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Arthur Tatnall *Editor*

Encyclopedia of Education and Information Technologies

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With 339 Figures and 183 Tables

 Springer

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Preface

Computers today invade almost every aspect of our lives and are used in many different ways, education being no exception. This, of course, was not always the case, and computers today are used in many different ways from the calculating machines from which they evolved. The *stored-program electronic digital computer* first appeared in the 1940s, but computing goes back much further than this and can be traced to earlier technologies including the abacus, Antikythera mechanism (ancient Greek analog computer), Napier's bones (logarithms), and Babbage's difference engine that performed many of the mathematical tasks now performed by computers. From a machine designed to perform calculations, the computer soon evolved into an information processing and communications machine that became indispensable around the world.

University courses in computing began in many countries in the Departments of Mathematics in the late 1940s. The question whether *Computer Science* was a branch of science, a branch of engineering, or whether it was something else entirely unique was long discussed, and it was not until the mid-1960s that university courses in Computer Science as a separate discipline became widely available. Largely due to increased computerization of government departments and the growing computing needs of businesses, in the 1970s university courses in *Business Computing* began to appear. These soon evolved into what we now call *Information Systems*. Today, university courses make use of computers in many ways in both teaching and in research.

It was in the 1970s that school computing began around the world when a small number of schools in some countries began using shared minicomputers along with punched cards for teaching programming in conjunction with facilities at local universities. This mostly related to mathematics, and the teachers involved were typically mathematics or science teachers who had done some computer programming in their university degree courses. The arrival of relatively low cost microcomputers such as the Apple II and Tandy TRS-80 in the late 1970s marked the beginning of the growth of computers in schools. In the 1980s, the curriculum of many schools included teaching *Computer Literacy* as well as some *Computer Science*. Computer use in subject areas followed with the use of databases, spreadsheets, and word processing. Perhaps the biggest innovation though was word processing, which was quickly adopted in many subject areas. Since then, the advent of the Internet, World Wide Web, Wi-Fi, Bluetooth, mobile computers, iPads, mobile phones, and social media has changed the face of educational

computing out of recognition and led to the ways we use computers in education today.

To confuse the issue, there has always been some debate about a title for this area: Computer Science, Computing, Information Technology (IT), and Information and Communication Technologies (ICT) are all titles used by people in different countries. Information Technology today is approached in education in two different ways: teaching about computing in some shape or form (Computer Science) or making use of computers in different subject areas.

This encyclopedia covers all aspects of the use of computers and information technology in every part and form of education. It covers aspects of teaching about computing and use of IT in many different subject areas. It covers computing in early childhood education, computers in primary schools, computers in secondary schools, computer-related professional training and professional development, computers in universities, and computers in training colleges. All chapters have been peer-reviewed by at least two reviewers.

The topics covered include IT and lifelong learning, assistive technologies for special education and people with disabilities, history of educational computing, IT education resources, educational computer games, mobile technologies, designing new educational products, innovation and adoption, computer science, information systems, classroom computing, using the computer as a teaching aid, teachers and IT, computing education research, online learning, global policies and issues, social networking, digital literacy, educational assessment using IT, educational management, IT issues in developed and developing countries, and sociocultural issues with this technology.

Many teachers and academics have worked on writing chapters, and the encyclopedia has been assembled by a team of Section Editors. The encyclopedia has contributions from authors from universities, schools, government departments, and institutions in the following 46 countries: Australia, Austria, Bahrain, Belgium, Canada, China, Colombia, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, India, Ireland, Israel, Italy, Japan, Kazakhstan, Kuwait, Lithuania, Macau, Malaysia, New Zealand, Nigeria, Norway, Oman, Poland, Portugal, Russia, Saudi Arabia, Serbia, Singapore, South Africa, Spain, Sweden, Switzerland, the Czech Republic, the Netherlands, the Philippines, the UAE, the UK, and the USA.

A hardworking editorial team has brought this encyclopedia into existence through the selection of and invitation to authors and the review of their work. The team consisted of Sigrid Schubert (University of Siegen, Germany), Eric Sanchez (*University of Fribourg, Switzerland*), Jari Multisilta (*Tampere University of Technology, Finland*), Arthur Tatnall (Victoria University, Australia), Vassilios Argyropoulos (University of Thessaly, Greece), Sam Goundar (Victoria University of Wellington, New Zealand), Don Passey (Lancaster University, UK), Bill Davey (*RMIT University, Australia*), Monique Grandbastien (Université de Lorraine, France), Tony Jones (*University of Melbourne, Australia*), Javier Osorio (*Universidad de Las Palmas de Gran Canaria, Spain*), Faten Abdel-Hameed (University of Bahrain, Bahrain), and Joseph Chao (Bowling Green State University, Ohio, USA).

This encyclopedia aims to offer teachers, scholars, parents, and the general public an indication of the breadth and importance of how Information Technology is used in all forms of education. It illustrates the many ways in which IT is being used in education.

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May 2020

Arthur Tatnall

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Section Editor: *Vassilios Argyropoulos*

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Section Editor: *Don Passey*

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Section Editor: *Anthony Jones*

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Computers in Secondary Schools

Section Editor: *Sigrid Schubert*

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Section Editor: *Bill Davey*

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Section Editor: *Monique Grandbastien*

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Computing in Early Childhood Education

Section Editor: *Anthony Jones*

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Section Editor: *Arthur Tatnall*

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Developed and Developing Countries

Section Editor: *Sam Goundar*

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Section Editor: *Jari Multisilta*

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Section Editor: *Faten S. M. Abdel-Hameed*

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Educational Management

Section Editor: *Javier Osorio*

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Section Editor: *Eric Sanchez*

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Section Editor: *Don Passey*

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Section Editor: *Arthur Tatnall*

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Section Editor: *Don Passey*

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Section Editor: *Bill Davey*

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Section Editor: *Jari Multisilta*

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Section Editor: *Arthur Tatnall*

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Teachers and IT

Section Editor: *Sam Goundar*

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Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools	Teacher Education, Thinking About ICT Video-Enhanced Feedback

About the Editor



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Dr. Arthur Tatnall began his career as a secondary school physics and mathematics teacher before getting into computing in the late 1970s when his school obtained a 16k Apple II computer. In the 1980s he went on to become a *Computer Education and General Curriculum Consultant* and later worked as *Educational Computer Systems Analyst* at the Victorian State Computer Education Centre. He served as *Chief Examiner* for Year 12 Computer Science in Victoria from 1984 to 1991. In 1988 he took up a university position teaching and researching Information Systems at Footscray Institute in Victoria and then moving to Western Institute before the two institutions combined to form Victoria University. He has also been *President of the Computing in Education Group of Victoria*, *Director of the Victorian Information Technology Teachers Association*, and *Board Member of the Australian Council for Computers in Education*.

Arthur has undergraduate degrees in Science, Education, and Computer Science. In his Master of Arts research, he investigated the history of the origin of the discipline of Information Systems (IS) in Australia and how universities then devised IS curricula. In his Ph.D., he used actor-network theory to investigate the adoption of Visual Basic into the curriculum of an Australian university.

Arthur is a Fellow of the Australian Computer Society (ACS) and has served on the ACS Victorian Branch Executive Committee. He has been Editor of the *ACS Victorian Bulletin* and a member

of the ACS ICT Heritage Project. He is active in the International Federation for Information Processing (IFIP) as a member of WG 9.7 (History of Computing), WG 3.4 (Professional and Vocational Education in ICT), and WG 3.7 (IT and Educational Management).

He has authored and coauthored a number of computing textbooks and edited several IFIP Conference books. He was also Editor of the *Encyclopedia of Portal Technology and Applications* and, from 2009 to 2016, Editor in Chief of the *International Journal of Actor-Network Theory and Technological Innovation*. He is currently Editor in Chief of the journal of *Education and Information Technologies* (Springer Nature) and has published widely in journals, books, and book chapters.

Arthur's research interests include technological innovation, history of technology, computers in education, IT in educational management, information systems curriculum, and project management. Much of his research is based on the use of actor-network theory.

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A

Aboriginal

- ▶ Safe Frames, Essential Determinant for Educational Technology Implementation in an Indigenous Context

Acceleration

- ▶ Assistive Technology and the Gifted Learner

Access

- ▶ Assisting Elderly Non-computer-Literate People with Computer-Based Communications

Accessibility

- ▶ Assisting People with Physical Disabilities Through Technology

Accountability

- ▶ Support for School and Institutional Improvement and Accountability

Action Plan

- ▶ Open Educational Resources and Distance Learning, Challenges and the Way Forward in Higher Education

Active Aging

- ▶ Assisting Elderly Non-computer-Literate People with Computer-Based Communications

Active Learning

- ▶ Digital Technologies in Higher Education, Learning Challenges

Actor-Network Theory

- ▶ Assisting Students with Learning Disabilities Through Technology

Actor-Network Theory (ANT)

- ▶ Technological Innovation in ICT for Education

Adapting to New Software and Hardware

► [Sustaining Digital Technology Use in Professional Communities](#)

Adaptive Learning

► [Artificial Intelligence in Education](#)

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools

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Synonyms

[Cognition](#); [Innovation diffusion](#); [Teaching/learning system](#); [Technology acceptance](#)

Introduction

The effects of technology acceptance and innovation diffusion behaviors on information and communications technology-enabled teaching/learning systems (ITLS) adoption attract increasing attention among primary school teachers (Wu and Liu 2015). In particular, Internet-based e-learning has been considered one of the important ICT tools for knowledge providers and receivers to create an exchange process in cyberspace for knowledge development. The system adoption is generally a multidimensional issue that needs to consider such issues as providers' teaching behaviors (e.g., teaching cognition and ICT use preference), characteristics of ITLS (e.g., material presentation, diversity,

and adaptability), and receiver's learning behavior (e.g., learning cognition and ICT adoption propensity) (Bertacchini et al. 2012).

In particular, the provider's teaching behavior based on his or her cognitive system is one of the major determinants of the ITLS utilization (Mampadi et al. 2011). When ITLS providers attempt to describe how effective their tools will be in assisting teachers to develop their ITLS programs, the characteristics of their cognitive system are important to the system design characteristics. For example, a few teachers may need an online community to ease mutual socialization for knowledge exchange and development, whereas others prefer teaching materials developed using multimedia technologies. Certain teachers in a secondary school are unlikely to participate in an online community because of the various cognitions of ICT applications, which need strategies and policies to deal with this issue (Wang and Lu 2012).

One of the relevant methods to motivate pre-service teachers to utilize ICT-enabled tools in teaching is to narrate the existing offerings in the training courses to ITLS available in schools and the methods of using them. This process signifies that the ITLS use perception of teachers varies and should be retreated to maximize the ITLS use with respect to teaching performance. As such, instructors in the current educational environment are required to assume such diverse roles in education as mentors, lifetime learners, curriculum designers, curriculum implementers, teaching assistants, student motivators, peer counselors, teaching consultants, and learning partners. Liaw et al. (2007) conducted a survey and indicated that the teacher-led feature is one of the major determinants that substantially influence the learners' attitude toward e-learning as an effective learning tool. This result implies that teacher roles considerably influence the learning performance under ITLS.

Considerable effort has been exerted to the research, development, adoption, and evaluation of ITLS. In general, emphasis focused on the learner side to enhance the learning performance without considering the personality style of the instructors with respect to the adoption of the cognition-relevant ITLS. As an initiator or

facilitator of learner e-learning use, the propensity of a teacher in using ITLS is crucial for learner use of e-learning. The e-learning critical success factors can be generally grouped into four facets, namely, instructor, student, ICT, and university support (Selim 2007). In particular, the instructors' use of e-learning environments is actually affected by their opinions and propensity to perceive web-based activities and computer-assisted learning. Therefore, the understanding of teachers' adoption intention of ITLS should be deepened to determine the relationship between their cognitive style and propensity to adopt. Accordingly, this study analyzes the factors that explain teachers' willingness or unwillingness to adopt an e-learning system and determine the role of the instructor cognitive styles.

The features of the cognitive style are mainly thinking styles, problem solving, individual perception, and the role of memory and other cognition shown by typical personal traits (Allinson and Hayes 1996). The intuitive and analytical styles, which are called cognitive style index (CSI), are among the many differentiating cognitive styles. The intuitive style prefers free and less-structured thinking behavior, whereas the analytical style is to think with further logic and structure. For example, "People think that I prefer rapidly browsing learning materials" is an intuitive style. By contrast, "People think I usually analyze learning materials with logics" is analytical.

A specific ITLS has been developing its own characteristics that often involve the technology perception and cognitive behavior of users. Its adoption propensity is strongly related to the technology acceptance behavior (e.g., perceived usefulness and perceived ease of use) and technology use behavior (e.g., perceived compatibility) of instructors. The study in the chapter incorporates the behavior of technology acceptance (Davis 1989) and innovation diffusion (Rogers 2003) to derive the research model. An empirical study is conducted on elementary school teachers to analyze the determinants of the adoption intention of ITLS. The moderation effect of the cognitive style on the adoption attitude of ITLS is also presented.

Literature Review

Behavior of Technology Acceptance

The intention of technology acceptance is linked mainly to perceived usefulness and perceived ease of use (Davis 1989) and has been broadly used to analyze the willingness of innovative technology. This idea argues that individuals believe that using a particular technology or system will improve their performance level. When a system is useful and easy to use, it will produce positive intention conducive to adoption. Teachers often consider ITLS as a beneficial tool because they think it can reduce the cost of teaching materials and of teaching itself, enhance the personal accomplishment of information and professional knowledge, and improve teaching performance. The perceived usefulness is related to the course performance in the analysis of the factors that contribute to a successful e-learning environment. The perceived ease of use refers to the extent of personal needs to use a specific technology or system. This study attempts to evaluate whether these factors are also the determinants related to the adoption willingness of ITLS for teachers in primary schools and whether they are moderated by the cognitive styles. The first and second hypotheses are as follows:

- H1: Perceived usefulness will significantly and positively influence the attitude toward the adoption of ITLS.
- H2: Perceived ease of use will significantly and positively influence the attitude toward the adoption of ITLS.

Innovation Diffusion

Innovation diffusion theory is proposed to explain the attitude toward the behavior of technology use, including cognition, persuasion, decision, implementation, and confirmation (Rogers 2003). The behavior of innovation diffusion is linked to five major factors, namely, (1) comparative advantage, (2) compatibility, (3) complexity, (4) to try, and (5) observability. Comparative advantage and complexity factors are considerably similar to perceived usefulness and perceived ease of use, respectively. Compatibility refers to

the similarity between teachers' behaviors in teaching and their original teaching methods if the use of ITLS is considered. This factor is positively related to behavioral intention and perceived education quality to use ITLS that offers online learning courses. Adopting ITLS to assist in teaching is not simply an issue of using ICT tools or their integration. Such issues as similarity of learning and teaching behavior (e.g., pull strategy) and educational policy set (e.g., push strategy) may also need to be considered.

For example, if teachers want to make the materials available in ITLS, then they probably should prepare based on their preferences for and perception of the required software, hardware, and e-materials. Thus, behavior and concept conflicts may occur, thereby probably decreasing the willingness to use the e-learning system. However, if the ITLS education is a set educational policy wherein a teacher has to adapt to using ITLS, then the relationship between perceived compatibility and adoption attitude may change because compatibility may not be an issue for a teacher to adopt. In this case, theory of technology acceptance behavior may explain the situation that behavior is occasionally not self-controllable.

When ITLS enables teachers or students to attempt only part of it, the uncertainty of potential adopters is reduced. Understanding the willingness to attempt an ITLS is highly important to the adoption attitude of ITLS. The advanced ICT has already developed innovative tools and strategies, such as the game-based learning system for learning educational materials in a playful manner, thereby facilitating the educational process. The experience of human-computer interaction frequently marks the playfulness as a predictor of innovation technology use. The effect of edutainment (education plus entertainment) on the increase in motivation was linked to interest/enjoyment and competence (Bertacchini et al. 2012). The playfulness is likely a predictor of the adoption attitude of ITLS for elementary school teachers.

H3: Perceived compatibility will substantially influence the positive attitude toward the adoption of ITLS.

H4: Trialability will substantially influence the positive attitude toward the adoption of ITLS.

H5: Perceived playfulness will substantially influence the positive attitude toward the adoption of ITLS.

H6: A positive attitude will substantially influence the ICT adoption intention.

Cognitive Behavior

Social cognitive theory that is used in explaining learning processes is central to understanding the personality of the learners and instructors (Bandura 1986). Learning is explained in terms of a model, in which behavior, cognition, and environment combine as interacting determinants of one another. Such process is affected by the students' own thoughts, self-beliefs, and interpretation of learning subjects. However, training is believed to be shaped continuously by factors within the environment and thinking behavior of trainers, particularly the technology use perceived by instructors. In general, the stock knowledge of instructors probably interacts with design manipulations when they adopt technology-based learning materials. Teachers use their prior knowledge as basis to possibly prefer ITLS with media-enriched tools to assist in externalizing their knowledge, such that their students can efficiently obtain, relate, and restructure knowledge elements to develop their own knowledge structure. Accordingly, an instructor may argue that reading additional texts (e.g., ICT-based Wiki) can improve performance better than talking to people often (e.g., ICT-based Google talk) based on his or her cognition or experience. This argument may substantially influence the use propensity of ITLS.

The role of cognitive style varies but generally centers on the impact on learners. Research had limited focus in considering the instructor viewpoint by concentrating on the cognitive characteristics that may be linked to the design and adoption preferences. Thus, instructor perception with respect to the cognitive characteristics on the use of ICT tools will likely be related to learning performance. The basic classification of cognitive style is based on the viewpoint of human perception, which can be divided into intuitive and analytical perceptions (Allinson

and Hayes 1996). The analytical type has characteristics in the method of organizing information and messages, such as concise thinking, logical reasoning, analytical functions, and further attention to detail, structured problem-solving style, and methodical approach. The intuitive type tends to involve imagination, understanding, metaphor, rhythm, attitudes, and emotions. This type often changes over time. Problems are preferably solved without any restriction. Cognitive style may influence the teacher adoption intention of ITLS. Thus, the following six hypotheses are formulated:

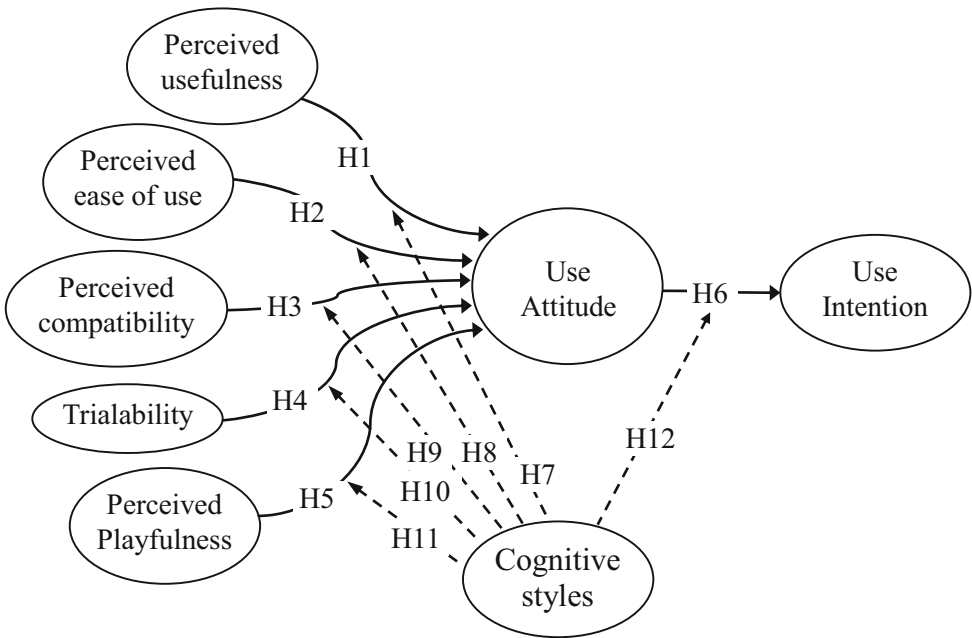
- H7: Cognitive style substantially moderates the effect of perceived usefulness on the adoption of ITLS.
- H8: Cognitive style substantially moderates the effect of perceived ease of use on the adoption attitude of ITLS.
- H9: Cognitive style substantially moderates the effect of perceived compatibility on the adoption attitude of ITLS.

- H10: Cognitive style significantly moderates the effect of trialability on the adoption attitude of ITLS.
- H11: Cognitive style significantly moderates the effect of perceived playfulness on the adoption attitude of ITLS.
- H12: Cognitive style significantly moderates the effect of adoption attitude and intention of ITLS.

Method

Model

Technology acceptance and innovation diffusion theories are employed to describe the ITLS adoption behavior. The research model presented in Fig. 1 is developed based on the formulated hypotheses. The moderating role of cognitive styles is also analyzed. The independent variables are perceived usefulness, perceived ease of use, perceived compatibility, trialability, and perceived playfulness. By contrast, the dependent variable is



Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Fig. 1 Research Framework

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools,
Table 1 Descriptive statistics

Data items	Category	Subjects (<i>N</i> = 340)			Percentage		
		All	Intuitive	Analytical	All	Intuitive	Analytical
Gender	Male	66	31	35	19.41%	46.97%	53.03%
	Female	274	153	121	80.59%	55.84%	44.16%
Teaching age	1–5 years	46	23	23	13.53%	50.00%	50.00%
	6–15 years	178	106	72	52.35%	59.55%	40.45%
	16–25 years	92	46	46	27.06%	50.00%	50.00%
	Over 26 years	24	8	16	7.06%	33.33%	66.67%
Education degree	Specialist	43	20	23	12.65%	46.51%	53.49%
	College	176	92	84	51.76%	52.27%	47.73%
	Graduate or above	121	72	49	35.59%	59.50%	40.50%
Weekly hours to use ICT in teaching	0–5 h	178	106	72	52.35%	59.55%	40.45%
	6–10 h	65	32	33	19.12%	49.23%	50.77%
	11–15 h	63	31	32	18.53%	49.21%	50.79%
	16–20 h	24	12	12	7.09%	50.00%	50.00%
	20 h or above	10	3	7	2.91%	30.00%	70.00%

attitude conducive to the intention of ITLS adoption.

Sample

The research population comprised the primary school teachers in a municipality that agreed to participate in the research. The subjects were encouraged to follow the city government's education policy to develop advanced teaching models in primary schools, particularly the ITLS adoption. The city has 49 primary schools and a total number of 2645 teachers. The number of samples for each school was based on the proportion of school teachers to the total number of teachers. Random sampling was conducted to distribute the questionnaires to the class teachers, subject teachers, and administrators. A total of 420 questionnaires were mailed or delivered personally to the schools that accepted participation. The data collection period was 4 weeks. The basic information of the subjects includes gender, teaching age, educational level, and average number of hours per week they use ITLS in teaching.

A total of 340 valid samples were returned (80.95% valid return rate). Of the 340 respondents,

184 were intuitive style and 156 were analytical. Table 1 shows the descriptive statistics. The majority of the respondents were female teachers (80.59%) and most have been teaching for at least 6 years. For the proportion of basic information of the intuitive and analytical types, teachers generally had teaching experiences “within 6 to 15 years” in both styles. Those who teach using the intuitive style account for 58%, whereas 46% employ the analytical style. For the weekly hours using ICT-enabled systems in teaching, most subjects were in the range of “0 to 5 hours,” 54% and 45.5% of which were of the intuitive and analytical types, respectively.

Measure

A questionnaire was designed as the data collection instrument (see Table 2). First, nine items were developed for two variables in the technology acceptance composite. For example, the item “I think ITLS can improve my teaching efficiency” is used for the variable of usefulness. Second, for the innovation diffusion composite, three items were developed for perceived compatibility and three for trialability. For example, the

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 2 Questionnaire design

Composites	Factors	Items
Perception of technology acceptance	Perceived usefulness (PU): subjects perceive that ITLS is useful for their teaching work	PU1: I think ITLS can improve my teaching efficiency
		PU2: I think ITLS can improve the quality of my teaching
		PU3: I think ITLS can ease my teaching work load
		PU4: Overall, I think ITLS is useful
	Perceived ease of use (PEU): subjects perceive that ITLS for teaching work is easy to use	PEU1: I think ITLS is not difficult to use
		PEU2: I think learning how to use ITLS does not need too much effort
		PEU3: I think learning how to use ITLS does not need much time
		PEU4: Overall, I think ITLS is easy to learn
Perception of innovation diffusion	Perceived compatibility (PCOM): subjects perceive that they do not have to change too much of their existing behavior or skills while using ITLS	PCOM1: I think using ITLS to teach is similar to the existing tools
		PCOM2: I think the way to use ITLS in teaching is similar to the way I use other tools
		PCOM3: Overall, I think using ITLS is consistent with my current teaching behavior
	Triability: subjects perceive that trying ITLS is necessary before using it	TRI1: I think it is better to try ITLS before actually adopting it
		TRI2: I think I am willing to adopt ITLS if I am allowed to try it
		TRI3: Overall, I think ITLS should be triable
	Perceived playfulness (PP): subjects perceive that using ITLS is playful and enjoyable	PP1: I think ITLS is interesting.
		PP2: I am happy when I use ITLS
		PP3: I think using ITLS is playful
		PP4: I think using ITLS is enjoyable
		PP5: I think using ITLS can help me explore new things
		PP6: Overall, I think ITLS can enhance teaching playfulness
Attitude	Attitude (ATT): subjects perceive that using ITLS is a positive idea	ATT1: I think using ITLS is a good idea
		ATT2: I think I have a positive attitude toward the use of ITLS
Intention	Intention (INT): users perceive that they will continue (or intend) to use ITLS	INT1: I will be willing to continue using ITLS
		INT2: I am happy to use ITLS now and in the future
		INT3: Overall, I am (will be) sure to use ITLS in teaching

Do you have any comments or opinions on the ITLS adoption? Additional information on your school regarding the use of ITLS is particularly welcome (e.g., policy and strategy)

item “I think the way to use ITLS in teaching is similar to the way I use other tools” is used for the variable of perceived compatibility. Six items were used for the variable of playfulness. For example, the item “I am happy when I use ITLS” is used for this variable. Lastly, two items for attitude and three items for intention were used.

Each variable was measured based on the five-digit Likert rating scale (from 1 to 5) using bipolar descriptors for each question. An open question was also provided at the end of the questionnaire for subjects if they have additional information to provide (e.g., policy, training programs). The CSI questionnaire was used to differentiate the analytical subjects from the intuitive ones. For example, “When I make a decision, I will think calmly then carry out and

complete all relevant factors” is used for the analytical style. By contrast, “I am better in generating ideas rather than handling data of precise information” is used for the intuitive style.

Results and Discussion

Reliability

Table 3 shows the reliability test results. The Cronbach’s α of the overall model was 0.906. The exploratory factor analysis (EFA) using principle component analysis (PCA) was conducted to measure the concepts because the proposed model contained several factors. The PCA and varimax of the orthogonal rotation to derive the factors were utilized. The explained total variance was 79.46%, which is above 60%. Table 4 lists the

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 3 Research variables of cronbach’s α coefficient

Factors	Items	Mean	S.d.	Item to total	Cronbach’s α
Perceived usefulness (PU)	PU1	4.41	0.78	0.633	0.836
	PU2	4.34	0.80	0.694	
	PU3	4.55	0.64	0.654	
	PU4	4.55	0.64	0.707	
Perceived ease of use (PEU)	PEU1	4.26	0.81	0.711	0.914
	PEU2	4.04	0.96	0.856	
	PEU3	3.96	0.98	0.820	
	PEU4	4.09	0.92	0.839	
Perceived compatibility (PCOM)	PCOM1	4.08	0.86	0.828	0.897
	PCOM2	4.12	0.82	0.861	
	PCOM3	4.44	0.91	0.711	
Trialability (TRI)	TRI1	4.48	0.73	0.698	0.882
	TRI2	4.53	0.72	0.863	
	TRI3	4.50	0.69	0.759	
Perceived playfulness (PP)	PP1	4.40	0.76	0.662	0.843
	PP2	4.23	0.79	0.708	
	PP3	3.27	1.31	0.335	
	PP4	4.06	0.89	0.793	
	PP5	4.12	0.83	0.790	
	PP6	4.09	0.85	0.702	
Attitude (ATT)	ATT1	4.40	0.70	0.813	0.895
	ATT2	4.26	0.78	0.813	
Intention (INT)	INT1	4.34	0.76	0.903	0.963
	INT2	4.32	0.78	0.937	
	INT3	4.30	0.83	0.928	
Overall Cronbach’s α					0.906

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 4 Factor analysis results

Item	Factors						
	PU	PEU	PCOM	TRI	PP	ATT	INT
PU 2	0.795	0.281	0.109	0.027	0.151	0.021	0.023
PU 1	0.783	0.129	−0.009	0.247	0.094	0.016	0.198
PU 4	0.743	0.127	0.254	0.172	0.227	0.092	0.214
PU 3	0.692	0.035	0.310	0.167	0.267	0.213	0.089
PEU 2	0.129	0.858	0.232	0.175	0.156	0.301	0.032
PEU 3	0.143	0.835	0.259	0.117	0.188	0.056	0.134
PEU 4	0.127	0.777	0.336	0.245	0.202	0.124	0.176
PEU 1	0.259	0.697	0.142	0.246	0.235	0.202	0.142
PCOM 2	0.196	0.390	0.789	0.219	0.173	0.312	0.302
PCOM 1	0.225	0.385	0.760	0.256	0.126	0.213	0.111
PCOM 3	0.214	0.322	0.662	0.233	0.313	0.010	0.105
TRI 2	0.189	0.226	0.219	0.853	0.186	0.104	0.179
TRI 1	0.107	0.188	0.193	0.799	0.131	0.189	0.152
TRI 3	0.267	0.194	0.134	0.790	0.229	0.234	0.165
PP 5	0.220	0.211	0.165	0.168	0.858	0.316	0.211
PP 6	0.222	0.193	0.138	0.129	0.834	0.165	0.079
PP 4	0.186	0.223	0.156	0.249	0.807	0.099	0.103
ATT 1	0.201	0.302	0.133	0.221	0.144	0.889	0.342
ATT 2	0.214	0.207	0.154	0.187	0.231	0.884	0.302
INT 2	0.230	0.198	0.231	0.126	0.244	0.323	0.919
INT 3	0.067	0.099	0.199	0.097	0.306	0.362	0.898
INT 1	0.091	0.087	0.318	0.213	0.292	0.378	0.878

1. KMO = 0.892; Bartlett's test of sphericity: *** $p < 0.01$

2. *PU* perceived usefulness, *PEU* perceived ease of use, *PCOM* perceived compatibility, *TRI* trialability, *PP* perceived playfulness, *ATT* adoption attitude, *INT* adoption intention

details. Factor loading was between 0.662 and 0.919, which is above 0.5.

The model validity test and significance of path coefficient were conducted. For the validity, the model satisfied three requirements, namely, (1) composite reliability (CR) (Cronbach's α) above 0.7, (2) average variance extracted (AVE) above 0.5, and (3) square root of AVE for a factor higher than the correlation coefficient of the other factors. Table 4 presents the test results. The CR value of PU (0.893) was above 0.7. The AVE of PU ($0.822 * 0.822 = 0.676$) was above 0.5, and its square root (0.822) in Table 5 was higher than the correlation coefficient of other factors. Table 6 presents the results of path significance. The explained variance of the independent variables and the dependent variables were 0.659 and 0.463, respectively, and were considered acceptable. Table 7 presents the test result of the

moderation effect. The discussion and implications are provided as follows.

Discussion

Research findings provide several contributions to research theory and practice. The current study describes the research arguments via a basic and rigorous review of literature. This research considers previous theoretical concepts and findings obtained for TAM, IDT, and cognitive styles. The ITLS characteristics are also considered to derive the potential factors that affect adoption attitude, including perceived usefulness, perceived ease of use, perceived compatibility, trialability, and perceived playfulness. This study confirms that perceived usefulness, perceived ease of use, trialability, and perceived playfulness

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 5 Model validation

	CR	PU	PEU	PCOM	TRI	PP	ATT	INT
PU	0.893	0.822						
PEU	0.939	0.467	0.892					
PCOM	0.938	0.534	0.716	0.913				
TRI	0.927	0.482	0.531	0.579	0.899			
PP	0.942	0.518	0.525	0.539	0.495	0.918		
ATT	0.951	0.634	0.610	0.584	0.624	0.690	0.952	
INT	0.976	0.562	0.494	0.547	0.593	0.588	0.681	0.966

1. The number in the bold diagonal course is the square root of AVE

2. CR composite reliability

3. PU perceived usefulness, PEU perceived ease of use, PCOM perceived compatibility, TRI trialability, PP perceived playfulness, ATT adoption attitude, INT adoption intention

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 6 Results of hypothesis test for all subjects

Independent variables	Dependent variables					
	Attitude toward ICT adoption			Intention toward ICT adoption		
	β	t value	p-value	β	t value	p-value
PU (H1)	0.259	6.357***	0.000	—	—	—
PEU (H2)	0.193	4.030***	0.000	—	—	—
PCOM (H3)	−0.015	−0.290	0.772	—	—	—
TRI (H4)	0.234	5.587***	0.000	—	—	—
PP (H5)	0.346	8.306***	0.000	—	—	—
	$R^2 = 0.659$					
	Adjusted $R^2 = 0.653$					
	$F = 128.09^{***}; p = 0.000$					
	Attitude toward ICT adoption (H6)			0.681	17.034***	0.000
				$R^2 = 0.463$		
				Adjusted $R^2 = 0.462$		
				$F = 290.16^{***}; p = 0.000$		

* $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.001$

PU perceived usefulness, PEU perceived ease of use, PCOM perceived compatibility, TRI trialability, PP perceived playfulness

substantially affect the ITLS adoption attitude conducive to adoption intention.

First, the perceived usefulness does have a substantial effect on adoption attitude (see Table 6). Education-supported tools or strategies need multiple channels and media-rich presentation to efficiently bring materials and knowledge into situations where teaching/learning occurs. Although ITLS in cyberspace is increasingly changing the way teachers are pursuing education, the analytical- and intuitive-styled teachers in primary schools likely accept ITLS as one of

the important tools to satisfy their teaching needs and wants.

Second, the perceived ease of use for the entire subject is significantly related to the adoption attitude toward adoption intention. However, the moderation test shows that analysis-styled subjects do not support this situation, thereby signifying that these subjects are more unlikely to care whether ITLS is easy to use. On the one hand, the type of analysis style has characteristics in the method of organizing teaching materials, such as concise thinking, logical

Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools, Table 7 Results of moderation test for the analytical and intuitive styles

Independent variables	Dependent variables					
	Analytical style (<i>N</i> = 184)			Intuitive style (<i>N</i> = 156)		
	β	t value	p-value	β	t value	p-value
	Attitude toward ICT adoption					
PU (H7)	0.148	2.660***	0.009	0.340	5.899***	0.000
PEU (H8)	0.048	0.539	0.590	0.238	4.168***	0.000
COMP (H9)	0.112	1.288	0.200	−0.052	−0.832	0.406
TRI (H10)	0.203	2.907***	0.004	0.232	4.292***	0.000
PP (H11)	0.466	7.039***	0.000	0.292	5.445***	0.000
	<i>R</i> ² = 0.676			<i>R</i> ² = 0.664		
	Adjusted <i>R</i> ² = 0.665			Adjusted <i>R</i> ² = 0.655		
	<i>F</i> = 62.61; <i>p</i> = 0.000			<i>F</i> = 69.63; <i>p</i> = 0.000		
	Intention toward ICT adoption					
Attitude toward ICT adoption (H12)	0.743	12.144***	0.000	0.755	12.661***	0.000
	<i>R</i> ² = 0.489			<i>R</i> ² = 0.468		
	Adjusted <i>R</i> ² = 0.486			Adjusted <i>R</i> ² = 0.465		
	<i>F</i> = 146.472; <i>p</i> = 0.000			<i>F</i> = 160.298; <i>p</i> = 0.000		

* $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.001$

PU perceived usefulness, PEU perceived ease of use, PCOM perceived compatibility, TRI trialability, PP perceived playfulness

reasoning, analytical functions, additional attention to detail, structured problem-solving style, and methodical approaches. These teachers tend to be considerably confident in analyzing and organizing teaching materials based on their own perceptions and preferences. However, these observations do not imply that the subjects with this cognition style completely ignore whether ITLS is easy to use. They are likely to be involved in the development of ITLS based on their preferences and may disregard ease of use as an adoption barrier.

On the other hand, intuitive people prefer diverse and less-structured thinking behavior. They tend to be substantially imaginative, empathic, and emotional with respect to the characteristics of the ITLS that they can use (e.g., online talk and animation). This view implies that they prefer teaching with substantial freedom or without excessive involvement in developing or using the ITLS and prefer ICT tools that are easy to use. Therefore, to promote ITLS in teaching, vendors, agents, and consultants should first understand the users' cognitive style. If the intuitive style is substantially dominant, then

additional attention should be focused on designing ICT tools that are easy to use.

Third, perceived compatibility is an insignificant factor for the intuitive and analytical groups. Accordingly, the compatibility of perception of the intuitive and analytical styles to the use of ITLS with the existing teaching behaviors is insignificantly linked to their ITLS adoption attitude. A response from a few subjects and their questionnaire responses showed a major reason. The subjects realized that they have to directly accept ITLS for their teaching endeavor because of the school policy. In general, the research subjects of the analytical and intuitive styles are not ICT professionals. ICT is merely a teaching aid. To date, the general use of the ICT experience or personal habits in teaching endeavors may be different for individuals. They have to change their existing teaching concepts and behaviors to adapt to the needs. Therefore, compatibility perception may be quite different with respect to its influence on the adoption attitude of ITLS.

Fourth, the subjects are significantly willing to attempt a teaching tool before they adopt it. Thus,

trialability is important to the enhancement of the adoption willingness of ITLS. In general, most elementary school teachers have non-IT-related professional backgrounds. They often have to train frequently and continuously use new technologies to ensure they know how to considerably operate these technologies.

Fifth, perceived playfulness shows a significant effect on the adoption attitude of ITLS. The ITLS or educational strategies need innovative technologies to satisfy the teaching/learning needs of the “e-generation.” Accordingly, responding to the needs may require varied media-rich materials to efficiently present educational information and knowledge in general and enjoyment-based learning process to motivate learning attitude in particular. Edutainment that combines education theory and entertainment may be one of the solutions that researchers, vendors, consultants, and government agencies consider for the development of ITLS. Lastly, adoption attitude is substantially related to adoption intention, which is a result that is also true for the analytical and intuitive subjects.

Moreover, the overall results imply that emphasis should be placed particularly on usefulness, trialability, and playfulness to attract the attention of school teachers. Toward this aim, primary teachers can explain that ITLS assists in presenting teaching materials in a media-rich manner, ease the communication with learners, develop an immersive environment, and enhance learning enjoyment, among others. In addition, the intuitive subjects prefer the easy-to-use ITLS, whereas the analytical subjects are unlikely to be concerned with the ease of use but do need involvement in the development of ITLS tools. These findings will be useful for ITLS providers and consultants to analyze the requirements of their school teachers, particularly the consideration for cognition characteristics. Moreover, the result discloses that the analytical and intuitive subjects are not excessively concerned with the issue of compatibility with respect to the effect of adoption attitude. Under the established education policy and strategy as well as the removal of the adoption barrier, this finding can serve as an aid for researchers, vendors, consultants, and

government agencies to persuade primary school teachers to adopt ITLS.

Conclusion

Primary school teachers are concerned with technology acceptance and innovation diffusion behaviors as the major determinants of ITLS adoption. Communication between instructors and learners via ITLS is a requirement in knowledge development because connections are established through externalization (instructor side) and internalization (learner side), thereby involving such variables as behavior, cognition, and technology-mediated environment. The cognitive styles were utilized to classify the sampled subjects and the moderation effect was tested to provide additional information on the adoption willingness of ITLS. Additional focus on the result limitations and implications should be provided with respect to the school level and cognition differentiation base.

A transition gap exists in the literature. Such issues as virtual instruction for the knowledge-provider side (e.g., online structural materials based on instructor cognition), ITLS for knowledge development platforms (game-based teaching/learning systems), and virtual self-learning process for the knowledge-receiver side (e.g., personalized materials based on learner cognition) should be considered in future research. Furthermore, the current research conducted a quantitative study without in-depth investigation on cognitive issues from a qualitative perspective. Therefore, a research direction may be a case or multi-case study to report additional findings on ITLS adoption and performance and offer suggestions thereafter for the ITLS vendors and agencies.

Cross-References

- ▶ [Leadership on Information Technology in Education](#)
- ▶ [Qualitative Methods, Lesson for Information Systems Researchers](#)
- ▶ [Teacher Education, Thinking About ICT](#)

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Adoption of Virtual Laboratories in India, Learning Assessments and Roles of ICT Skill Learning Tools

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Synonyms

ICT; Learning tools; Pedagogies; University education; Virtual labs

Introduction

In developing countries, literacy is crucial key for socioeconomic growth, and for achieving sustainable development goals, education platforms enabling remote or classroom didactic education must impact millions of students and teachers irrespective of geographic or infrastructure barriers. With the use of ICT in didactic laboratories, over the last three decades, several online educational tools have promoted enhanced learning and teaching experiences across communities of users (Youssef and Dahmani 2008; White 2008). Addressing the challenges of inquiry-based science learning, some of these ICT tools focus on augmenting skill training and supporting lecture courses with easily accessible online tools that can deliver laboratory skills through computer-based interfaces (Chu 1999; Harward et al. 2008; Diwakar et al. 2011; Heradio 2016). Virtual laboratories have also been presented as complementary education tools and as ICT platforms for sustainable education (Bocconi et al. 2013; Srivastava et al. 2013; Radhamani et al. 2016; Kumar et al. 2017). Besides, in biology, virtualization of wet-lab techniques have improved individualized education and increased the scope for flexible tools for students in remote areas in developing nations (Nair et al. 2012).

In India, government programs (MHRD 2016) for exploring e-learning were initiated for facilitating education for the masses and towards connecting teachers and students in formats including recorded lectures, smart boards, audio and visual tools (Bijlani et al. 2012) and education tools, and mobile applications. Through such projects, there have been a significant number of online laboratories reported for high school education (Nedungadi et al. 2015) and University-level education (Raman et al. 2011; Achuthan et al. 2011; Srivastava et al. 2013; Diwakar et al. 2015; Radhamani et al. 2015). With an entire nation in focus, Virtual Labs project, launched by Ministry of Human Resources Development (MHRD), under National Mission on Education through ICT, Government of India, was set up jointly by top-tier engineering institutes with the focus of developing and providing advanced training environment aimed at solving issues

faced classroom laboratory education. This team had designed, developed, and deployed experiments in biological sciences, physical sciences, chemical sciences, mechanical engineering, computer science engineering, and cybersecurity systems.

Virtual laboratories have been developed as multiple content and media models including animations (McClean et al. 2005; Radhamani et al. 2014), mathematical simulations (Parasuram et al. 2011; Murray 2002; Diwakar et al. 2014), remotely controlled hardware models (Ma and Nickerson 2006; Kumar et al. 2014), and analogue equivalents of realistic dynamics (Sridharan et al. 2016). Development (McClean et al. 2005; Diwakar et al. 2014) and deployment of virtual laboratories (Diwakar et al. 2014, 2016a) relate multiple elements connecting didactic education (Sajid et al. 2013; Herga et al. 2016), educators (Donovan et al. 1999; Houts et al. 2006; Diwakar et al. 2011; Svoboda and Passmore 2013), content (Eggen and Kauchak 1988; Sheorey and Gupta 2011), and access modalities (Youssef and Dahmani 2008; Noor-Ul-Amin 2013; Kumar et al. 2015; Alkhaldi et al. 2016).

Virtual Laboratories as an E-Learning Platform in India

Since 2009, we were involved in the development and deployment of virtual laboratories (www.vlab.amrita.edu) to complement classroom courses and accessible freely over the internet. As a consortium, India's Virtual Labs project had developed over 1000+ experiments for undergraduate and postgraduate students and as tools for teachers (Diwakar et al. 2015, 2016b). The target of development of such laboratories was handling insufficiency in numbers of trained experts for educating millions of graduating STEM students, unavailability of expensive hardware or experimental setups, and ability to enable extended access unrestricted by geographical or time constraints (Huang 2003; Diwakar et al. 2012).

The development of content was based on syllabi in most universities and modified to

suit teacher-independent education in and outside classrooms (Diwakar et al. 2010; Raman et al. 2011, 2014). India's virtual labs were also developed to cater towards resource or content unavailability and to help teachers and institutions who faced regression in student interests in science and technology experimentation (Diwakar et al. 2011; Achuthan et al. 2011).

Virtual labs were deployed in three modalities. Animation-style labs involved non-interactive or interactive graphical emulations capturing an experiment in terms of manipulating materials and equipment, or the temporal procedure including critical to-dos and do-nots (Radhamani et al. 2014). Simulation-based virtual labs employed mathematical approximations to generate realistic yet computationally feasible emulations of real-world conditions. Simpler mathematical models like logistic growth, predator-prey equation, spiking neuron models help resolve complex biological properties with equivalents for pedagogical benefits (Parasuram et al. 2011; Diwakar et al. 2016a). Remotely controlled experiments enable access to remote equipment and serve as an interface to perform real experimentation or with analogue equivalents serve to virtualize real experiment practice and data collection. Such experiments serve to help reduce accessibility or lab usage issues (Freeman et al. 2012; Kumar et al. 2014, 2015; Vijayan et al. 2017). The national platform consortia had established more than 1000 online experiments and are freely available via <http://vlab.co.in>.

Comparative Analysis of Virtual Labs

The cost-benefit analysis was estimated by comparing direct and indirect costs of laboratory skill training with and without virtual laboratories (Achuthan and Murali 2015). With an increase in student performance higher than 80% (Achuthan et al. 2014; Achuthan and Murali 2015) in over 40% students using physical lab to around 70% in students using both platforms, evaluations related the efficacy of virtual labs in classroom education.

The study related learning outcomes, time for learning, setup cost, safety, and facility requirements and assumed 800 square feet classroom for laboratory education and appraised 48% savings in tangible costs with virtual laboratories instead of physical laboratories suggesting additional training hours could be cost-effective, if performed on virtual platforms rather than physical laboratories. A cost order of Indian rupees 3 million was shown as a comparison for physical laboratories and virtual laboratories performing chemistry experiments being used in resource-restrained environments. The study also suggests selection of experiments could be based on cost, facilities, safety, time, and learning modalities relating physical laboratory, virtual laboratory, expensive physical laboratory, or remotely controlled laboratory choices. Physical labs and expensive physical labs (with equipment or resources being more uncommon) were not feasible for situations involving large number of student learners. Our study suggested low maintenance yet scalable labs were significantly cost-effective.

Evaluating Virtual Laboratory Usage

Learning outcomes have been shown to be improved by content consumption in addition to quality of learning material (Collis and Moonen 2001; Anderson 2007). Analyzing teacher-student interactions (Chu 1999; Sousa et al. 2010) and the usability of ICT tools (Bocconi et al. 2007; Vilaseca-Requena et al. 2007; Nair et al. 2012; Fathima 2013) such as virtual laboratories have been done across several case studies in multiple modalities (Guma et al. 2013; Achuthan et al. 2014; Kumar et al. 2015).

Another study had taken animations and simulations-based virtual laboratory and had evaluated the relative advantage, ease of use, and perceived usefulness among students and teachers (Diwakar et al. 2014). In technology acceptance model (TAM), usefulness is a criterion representing acceptance by users. The increase in usage also related to representation of general curriculum (Diwakar et al. 2011).

Usage/design scalability, deliverability efficiency, network connectivity issues, security issues in developing and implementation online laboratories in biotechnology courses were perceived critical in initial development and deployment of curriculum-specific virtual laboratories in India.

A previous paper (Diwakar et al. 2016a) had focused on the development, deployment, and implementation of 20 web-based virtual laboratories involving more than 170+ online experiments in Biotechnology and Biomedical engineering disciplines on students across villages in India. Pedagogical studies on didactic undergraduate and post-graduate classrooms involving remote labs reported the usage trend beyond scheduled classroom hours and the effective use of remote labs as a learning material towards laboratory examinations. Perceived relative advantage for remote lab users indicated the use of online labs as a next-gen interactive textbook for teachers and students in practical skill education. A small percentage of users reported learning issues in connection with poor internet connectivity and device failures. This implied several practical issues need to be resolved before deploying virtual and remote labs as a massive online course. A study on neurophysiology virtual labs suggested employing ICT-based skill training complemented as a cost-effective methodology for enhancing neuroscience education especially, in financially and geographically challenged nations like India (Diwakar et al. 2014). Remote labs have also been assessed as a self-learning material for robotic education (Vijayan et al. 2017). Using metacognition, analytical thinking, and transfer of knowledge, virtual laboratories in chemistry indicated students showed augmented reflective learning and information retention when virtual labs were introduced before physical laboratory training (Achuthan et al. 2017). Alternate concepts of chemistry students on molecular symmetry were evaluated after students used virtual laboratories (Achuthan et al. 2018). The virtual lab-based study had suggested identifying concept-based learning as relevant for perceiving alternate concepts among learners.

Technology Adoption: Criteria and Design Restraints

Several diffusion-of-innovations theories and models have emerged in order to study community members' acceptance and assimilation of these innovations (Venkatesh et al. 2003). Understanding technology adoption and diffusion of innovation play a vital role in outreach extent of new technologies by determining acceptance factors and new adopters' behaviors. A general framework on the social impact of technologies on people can also provide insight into the characteristics of technology that may influence specific groups to adopt them (Chuttur 2009). Research on innovative technologies in education has recommended several factors including technology design, instructional methods, and students' characteristics contribute to the effectiveness of technologies (Raman et al. 2014).

Laboratory exercises in STEM (Science, Technology, Engineering, and Mathematics) areas often require effective skill acquisition and hands-on roles for sustained skill training. In such scenarios, a virtual laboratory has to be modelled to meet the user requirements, namely: data collection, data measurement, data analysis, equipment handling, discarding biological hazards, use of explosive chemicals, among others. With design of effective learning tools, online laboratories have improved better understanding, facilitated problem-solving skills, and facilitated observation quality in a class of students. This has allowed overcoming challenging aspects of traditional classroom education in geographically and economically backward institutes such as time-constraints and scarcity of laboratory resources for delivering a high-quality education (Radhamani et al. 2016; Diwakar et al. 2016a; Nutakki et al. 2017). Although technology platforms need to account usage time to assess behavioral patterns, there is no significant indication in the literature regarding time users need to spend with an innovation prior to making the decision to adopt it into regular practice.

Dissemination of Virtual Laboratories: An India-Based Model Approach

In 2011, a nodal center program was conceptualized for dissemination and involved induction of science and engineering education institutes partnering to become early adopters of innovation in their regional areas. The induction of nodal centers was based on an institute's interest to join the program and were ensured support and assessment tools. Classroom integration of content and virtual lab methods were introduced to teachers who were part of the nodal center. Workshop-based hands-on training to faculty members was a part of the nodal center program. Assessment tools involved multiple choice questionnaires and descriptive questions for institutions and teachers to assess student's perception of technical concepts and to report the user experience. An annual conference allowed attendees to have hands-on training and opportunities to interact and provide feedback. Nodal centers and its associated students and teachers have been supported periodically with training sessions online and/or onsite. Today, we see a 25-fold increase in nodal centers compared to 2011 and more than a million active usages.

An analysis of technology adoption using Roger's model (Lee et al. 2011) suggests five types of adopters: Innovators (2.5%) were developer universities and institutes of national importance and ranked research intensive private universities. Early adopters (13.5%) included top colleges, large public or state universities and private universities (who became the nodal centers) tending to be opinion leaders in the social system and influenced the decisions of others. Combining the innovators and early adopters gets 16% and these two groups typically gives all the information of the product system. Early majority (34%) included colleges affiliated to universities that were rarely leaders but adopted new ideas and implemented them. Late majority (34%) were institutions that tried innovation after many had already incorporated and tested them. Both early majority and late majority comprise 68% of the adopter categories and their characteristics tend to be similar. Laggards (16%) were a few institutions

that were most difficult to be persuaded to adopt innovations and were insignificant diffusers of innovation.

User's Role in Autonomous Learning via Virtual Laboratories

Through feedback-based analysis, studies show students who performed virtual laboratories were able to learn concepts of experiments in an instructor-independent manner implying augmented self-organization abilities among students, facilitating reduced student-teacher interaction within crowded classrooms. Biology and biotechnology students preferred virtual laboratories as a pre-lab material to acquaint the basics of each experiment before practicing it in a wet lab. Workshop participants from India's rural and geographically remote non-city regions perceived remote labs as a distant education tool for equipment training and as a platform that allowed repeated usage of devices beyond scheduled classroom hours. Some issues related to poor usability of the remote labs were correlated to technical issues and inconsistent network connectivity. Deployments suggested low-cost and feasible FOSS-based implementation augmented student-teacher interaction and usage adaptability with remote labs.

Usage data from direct feedback suggested 82% users were able to use and adapted to self-organized learning through an ICT environment. Towards developing a more substantiated assessment of virtual labs, online feedback from 300,000 users received till January 31, 2018, were processed. Around 49,800 valid feedback inputs were evaluated for testing the virtual lab adaptability and its usage in the curriculum of university education in science and engineering disciplines all over the world. Fifty-eight percentage (28,884) of users rated virtual laboratories as an excellent tool for ease of use, 20% (9960) of users rated it as very good, and 18% (8964) indicated as it as a good platform for laboratory education.

A small percentage of users found it difficult to work with the virtual lab experiment and thus they

rated the technical support of virtual laboratories as average (2%, 996) or poor (2%, 996). This was related to students who faced connectivity or computer-usage issues while working with virtual lab experiments. Statistics showed that 62% (30,876) users supported the use of virtual laboratories as a complement to classroom education, 15% (7470) rated as very good, and 10% (4980) each suggested it as a good or an average tool after performing the virtual laboratories experiments. A small percentage of users (3%, 1494) rated it as a poor online material.

Among university-level teachers who participated in the remote lab workshop, 84% suggested that advanced technologies like remote controlling of lab equipment were helpful in their classroom scenario, whereas 16% did not favor use of such tools in blended learning. A participating college teacher commented: "Although the remote lab did not feel as real as the actual lab, remote labs allow students (to) practice the experiment many times and compare the results in order to have a better idea. This reduces our efforts in teaching the experimental concepts in the classroom so many times."

Virtual Labs and Extensions

While animation and simulation-based virtual laboratories were apt for most classroom-related practical courses, complementing remote student education may need specific design and deployment considerations while translating usage across regions and disciplines. Assessing trends of usage seem crucial to make such tools reliable for student learners in daily education. Biology students expect media-rich translations for higher usage and engineering students rely on content and interaction-rich environments. Remote laboratories with setup handling were not the most favorite among students in rural India. Such outcomes may also need more extensive testing. Effective learning strategies are yet to be perceived while major focusses have been on assessment of usage and use-related scoring. Our deployment and usage-based studies suggests nodal center outreach as early adopters was

effective for curriculum-related laboratory skill enhancement. Although continuous development and constant upgrades and new content are needed, statistics indicates steady increase of new users on virtual laboratory platform suggesting a general acceptance by teachers and students as a complementing laboratory skill-training resource.

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Advanced Computer Human Interactions

► [Games, Simulations, Immersive Environments, and Emerging Technologies](#)

Affordances

► [Affordances of Technological Connectivist Tools in Higher Education](#)

Affordances of Technological Connectivist Tools in Higher Education

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Synonyms

[Affordances](#); [Connectivist tools](#); [Higher education](#); [Social media](#)

Introduction

Connectivism is a learning theory which has been gaining ground in higher education in recent years. Its currency could be attributed to the rapid development of emerging technologies, which has impacted on the ways in which knowledge is produced and accessed (Downes 2005; Siemens 2004, 2009). As a theory, connectivism is often referred to as *networked learning* involving more than just the technology used to achieve the end result (Darrow 2009). Connectivism assumes that “knowledge is distributed across a network of connections and knowledge nodes” (Downes 2012). Social media can be used to connect to some of these nodes of knowledge

and facilitate further knowledge development on the premise of collaboration and sharing.

Although much has been written about connectivism since it was first coined by Siemens (2004) and Downes (2005) as a new learning theory, not much has been written about the affordances of connectivist tools for educational purposes. One of the problems with introducing connectivist tools into higher education is that academics are often not au fait with their use for educational purposes (Johnson et al. 2014; Seaman and Tinti-Kane 2013). In order to use these tools for educative purposes, higher educators would have to be inducted into their use in teaching and learning (Johnson et al. 2014; Stevenson and Hedberg 2011). To disseminate knowledge about connectivist tools, it is necessary to provide professional development for academics on the use of these tools for pedagogical purposes (Ng'ambi et al. 2013) and in reporting on how the academics experience these endeavors. As Anderson and Garrison (in press) note, the support needed to help teachers access and organize instructional content through the www is very important. "Teaching in a global, information-rich environment is a very different experience from teaching in a closed classroom." Unfortunately, academics remain uncertain and even fearful about the use of connectivist tools such as social media in their pedagogical practice as doing so requires them to abandon many conventional teaching and learning practices (Adria and Rose 2004). There is thus a need to investigate the use of connectivist tools such as Google Drive, WhatsApp, and Skype from the learner's perspective (Rambe and Nel 2014; Stevenson and Hedberg 2011).

This entry reports on the experiences of a group of university lecturers who were enrolled in an interinstitutional Postgraduate Diploma in Higher Education Teaching and Learning. The group of participants in the study was involved in an assessment task which entailed investigating a specific learning theory and developing a collaborative assignment on this theory. Our particular group was allocated "connectivism" as their learning theory. During the process of completing the task, the group researched on connectivism as

a learning theory and used connectivist tools such as Google Docs, Google Slides, Google Forms, WhatsApp, and Skype to investigate and develop their assignment. It was decided during the course of completing this assignment that group members were interested in disseminating their experiences of doing this task and their views on the pros and cons of connectivist tools. Toward this end, auto-ethnographic data were collected through a Google Forms where the participants shared their experiences and perceptions of connectivist tools and their various affordances.

This entry provides a brief overview of connectivism, connectivist tools, and the affordances of the specific tools which are considered in this entry. This is followed by a description of the methodology used, after which the findings are presented and discussed, as well as their implications for the higher education context.

Connectivism

In proposing connectivism as a learning theory for the digital age, Siemens (2004) characterizes it as a successor to behaviorism, cognitivism, and constructivism (Bell 2011). These antecedents to connectivism had their limitations in the form in which they viewed intrapersonal learning; their failure to address the learning that is located within technology and organizations; and their lack of contribution to the value judgments that needs to be made in knowledge-rich environments (Siemens 2004). Connectivism offers the platforms to shift teaching and learning practices in the twenty-first century.

In connectivism, learning takes place when learners make connections between ideas located throughout their personal learning networks, which are composed of numerous information resources and technologies (Dunaway 2011). One of the underlying principles of connectivism is that the capacity to know is more critical than what is currently known (Siemens 2008; Wang et al. 2014). Connectivism is driven by the understanding that decisions are based on rapidly altering foundations, where new information is continually being acquired and shared (Siemens

2004). From an epistemological point of view, learning in connectivism takes place by connecting to different nodes of knowledge across cyberspace, objectively analyzing and reviewing the gained knowledge. This process is aided through critical discussions and social interactions using social media. Technology used was blended in the form of cloud, social network, online voice integration, in this entry enhanced real time communication among participants and provided a platform for social creation of knowledge (Callaghan and Bower 2009; Rowe et al. 2013).

Connectivist Tools

Connectivist tools are used for learners to interact by creating and sharing knowledge, and are based on emerging or Web 2.0 technologies, made possible through the social web (del Moral et al. 2013). Shared working spaces for collaborative projects such as Google Drive and its various tools, such as Google Slides, Chat, Docs, Forms, etc., and WhatsApp and Skype for communication are some examples of connectivist tools which can be used for teaching and learning purposes. Through these connectivist tools, the learner is able to become an active and visible node in the learning network, contributing resources and ideas and participating in the collaborative creative process (Pettenati and Cigognini 2007). A clear implication of using connectivist tools and other social media is that the learners should be “active co-producers” of knowledge rather than “passive consumers” of content and subsequently that learning should be participatory (Selwyn 2012). Establishing how higher educators and learners perceive connectivist tools and how they understand the affordances of these tools is important for enhancing their use for educational purposes (Rambe and Nel 2014).

Affordances and Connectivist Tools

In recent years, the term “affordance” has increasingly appeared in educational literature, especially related to the use of online technologies in

education (Bower 2008; Conole and Dyke 2004; Day and Lloyd 2007; Gee 2014). In order to understand how attributes of online technologies interact with other elements of a learning context, including learners, teachers or educational practitioner, and the physical environment, it is necessary to understand affordance theories (Day and Lloyd 2007).

“‘Affordance’ refers to the perceived and actual properties of a thing, primarily those functional properties that determine just how the thing could possibly be used” (Salomon 1993 cited in Conole and Dyke 2004). When considering how to match learning tasks with technologies, it is useful to have a knowledge of the affordances of the technologies (Bower 2008). The term “affordance” was coined by the ecological psychologist Gibson (1977) and adapted by Norman (1988) for the design of everyday objects who distinguished between “real” and “perceived” affordances (Day and Lloyd 2007). In the original description that Gibson provides, an “affordance” is present as long as the organism is physically able to undertake the required action and as long as the possibility of executing that action is present (Bower 2008). In other words, affordances relate to the *action possibilities* (Gee 2014) that exist for connectivist tools. Affordances are therefore relational in that they concern the opportunities a connectivist tool offers and provides for action and how these qualities are taken up by the person using it.

Real affordances are not nearly as important as perceived affordances which signal to the user which actions can be performed and how they may be accomplished (Bower 2008). Gibson (1979) and James Paul Gee (2014) take this important point on perception of affordances forward by observing that unless an individual can *perceive* the possibilities connectivist tools provide, these tools are unlikely to be used effectively. In order to take advantage of the affordances or possibilities of a connectivist tool, “*effectivities*” are necessary (Gee 2014; Gibson 1979). Effectivities are “the set of capacities for action that the individual has for transforming affordances into action” (Gee 2014). These effectivities are thus necessary for academics and

students using connectivist tools in educational contexts so that they can be used in ways which take the learning forward. This is why it is important to engage with academics and students around the use of these tools for pedagogical purposes. Thus, the concepts “affordances” and “effectivities” are relational in that they are dependent on both connectivist tool and the ability and perception of the academic or student to use the tool for educational purposes.

This study sought to investigate was how the affordances of connectivist tools for teaching and learning were perceived by a group of learners who were educators in institutions of tertiary education. Specifically, the tools under examination were Google Drive, WhatsApp, and Skype.

During the course of engaging with the task, the group members became interested in the efficacy of utilizing connectivist tools to prepare and complete their assignment, particularly since they were located in geographically disparate spaces. The formal work of the assignment was conducted on Google Slides presentation, with collaborative writing and posting of graphics from group members and feedback to each other in the comments and chat boxes on the side. A Google folder for readings was uploaded for any useful texts that group members and the facilitator were able to source. In order to gather data for the study, a Google Forms questionnaire was sent to all group members, including the facilitator. At the same time, through the narrative, the participants were able to reflect on the experience. Auto-ethnography is defined as a qualitative research method that uses data about self and its context to gain an understanding of the connectivity between self and others within the same context (Ngunjiriet al. 2010). The auto-ethnographic researcher strives to examine his or her experiences in relation to others who have encountered similar circumstances as a way to identify a pattern, theory, or thread inherent to the group (Raab 2013).

The responses from the participants resulted in the close scrutiny of the affordances of the connectivist tools used in the assessment task, in terms of what the possibilities that various tools were able to provide or not provide for the

purposes of completing the assessment task given to the group.

Collaboration

The use of social media was perceived as enabling group collaboration and the ability to complete tasks assigned to group members, particularly since members were geographically separated. Rambe and Nel (2014) also noted that educators in the South African context reported on the opportunities that social media present for collaborative purposes. One of the participants commented, “from my experience, the use of these social media (i.e., WhatsApp, Google Docs) was an important aspect for the successful completion of the assignments (1&3).”

Familiarity with Connectivist Tools

One of the participants, who came from fields such as Information Sciences, indicated his familiarity with the use of social media: “Exposure and deep knowledge of IT made it easy for me to use social media.” Another participant found Google applications to be well designed from a technical viewpoint and was able to express this eloquently:

Google drive, presentation and docs are very user friendly. Google has been great by not attempting to redesign the interface, but rather use an interface that is familiar to most users. This makes all google applications easy to figure out and follow. The use of a great, simple intuitive interface is in my mind the key to their success and why I like using those platforms.

Participants found the use of tools for educational purposes to be more conducive when they were familiar with them, “WhatsApp was easy as I am familiar with it.” Conversely, when participants had not used the tool before or were unfamiliar with it, they found that their participation in the group activities was impeded, “Google presentations was not as easy to use as PowerPoint (which I am used to) as it was a bit slow and froze at times which was frustrating and it was unfamiliar.”

The Personal and Professional Boundaries with WhatsApp

The fact that participants found WhatsApp an easy connectivist tool to use did not mean that there were no problems with its application for educational purposes. Because participants were used to using this tool for social and personal purposes, participants found it more difficult to confine the discussion to educational matters. Rambe & Bere (2013) and Madge et al. (2009) have also noted the difficulties in traversing personal and professional boundaries in relation to mobile learning, similarly with Facebook for learning. One participant observed:

When it comes to WhatsApp use, it was the easiest of the tools as most people who own smartphones would utilise it on a day to day basis. That being said, the fact that it was easy to use, does not mean that it was not challenging to control what was being discussed.

Google Docs and Presentations, on the other hand, were not familiar to all participants, and they related these tools more with the tasks at hand than with socializing with their peers:

Google Docs and Presentations were new media platforms for me. I truly enjoyed learning about their potential use. Between the two I would say that Google Presentation was the most challenging as there are many options one could make use of.

Skype was also a familiar tool to most participants who had used it to communicate with others across geographical distances. Skype is a familiar social media platform for me, although I rarely use it.

Uneven Communication Through Social Media

Participant 1 and Participant 2 were great at communicating and interacting and drove our group assignments – I am grateful for this. Due to the distance, it was not easy to interact with Participant 3.

As can be seen in the above quote, some participants took more responsibility than others and made far more use of the connectivist tools to work on the

task, 'I tend to take the reins of group work when things are not going according to the original plan.'

Two group members took a leading position when working on the assignment - as one of them noted:

We had frank conversations about the course and the assignments. I always felt we had a good synergy. The other two members were a bit more distant in terms of the way we engaged but towards the end of Assignment 3 we had managed to establish a good rapport

Affordances of Tools as Perceived by Participants

The affordances of the different connectivist tools which were used regarding matching the teaching and learning tasks which the group members had to complete, and the processes involved in doing them, were commented on by the participants. They examined the attributes of the connectivist tools and what they made possible in terms of the group communication and abilities to collaborate on the course assignments.

Social Media

Group members were working academics who had little time to meet face-to-face with their work and family responsibilities, and social media provided a flexible platform for communication under these circumstances.

We only met face-to-face a few times, most communication was done via WhatsApp and the Google drive. There were times I realise I could have been better at communicating, this was due to pressures relating to work, home responsibilities and the course and having to prioritise each of these at different times.

WhatsApp

WhatsApp was seen as providing group members with immediate notification (Church and De Oliveira 2013) and coordination of upcoming deadlines: "With WhatsApp, the messages are instant although there is no face to face." Another member commented on the fact that WhatsApp was not used

to engage with the task but to arrange meetings and alert people to what was happening currently and what was being planned in the group:

WhatsApp was mainly used as an organizational tool with little to no interaction about the topic or task at hand. This I mainly ascribe to the laborious nature of entering text on a cellphone. But WhatsApp did provide social interaction promoting motivation and group coherence.

Google Drive

The Google Drive was used for working collaboratively on the task at hand both synchronously and asynchronously. The Google platform provided a much better platform for task-oriented interaction. The interaction taking place while all simultaneously working on the same project was amazing as interaction and comments in real time. However, our interaction was also asynchronous via comments and replies. Similar affordances of Google Drive were found by Rowe et al. (2013). Participants were highly enthusiastic about the affordances of Google Drive for the educational task:

The best platform for interaction was Google presentation with the built-in chat facility for task orientated learner-learner interaction. The reason it is so effective is because it has the chat function which allowed real-time chats, input, I think the true reason it was the most effective tool is because we were actually working on the task, thereby the conversations were guided to be task orientated and generally didn't shift into the social paradigm like WhatsApp for example. In addition, Google presentation allows for the asynchronous communication in the form of comments and input to which one can respond to at any time removing the time constraints. Furthermore, the comments are left directly on the task, making it easy to follow the meaning. Often in emails it becomes difficult to figure out exactly to what the comment pertains in particular if its attempting to address issues of formatting.

Google Drive was seen as the most useful tool for a number of different aspects of the task. In the participants' descriptions below, the accessibility, view-ability, read-ability, write-ability, share-ability, collaboration, move-ability, large size-ability, upload-ability, dialogue-ability, accessibility, synchronicity, revision-ability, browse-ability,

search-ability, build-ability, communicability, and interaction-ability are mapped out:

We could access the material from any location as well as share information among the rest of the peers.

Google drive allowed for uploading of large file sizes and instant feedback that involved commenting electronically. There was online collaboration of work activities among the group members involved in the project.

I think Google Drive was great to build and develop learner-content interaction. We could access the material from any location as well as share information among the rest of the peers

Google Drive was great to build and develop learner-content interaction. We could access the material from any location as well as share information among the rest of the peers.

For some participants, while Google Drive had many affordances, it was not sufficient altogether to accomplish what needed to be done. Some participants noted that they needed to do individual work to prepare for the collaborative work in groups:

group engagement with the content occurred in the creation phase on Google presentation, but it was often not in depth. The more in depth discussions occurred face-to-face.

Some form of content interaction occurred on Google presentation, but I think the majority of interaction with the content in my case occurred by reading and analysing pdf and word documents myself, in other words individual content engagement.

Google drive was where we could access useful and relevant content. I did however find a lot of articles and papers through my own searches online.

Skype

Skype was the choice of tool to have more extended conversations between group members who were distantly located geographically: "I used Skype for conferencing with group members at a distant away from the physical venue." However, Skype was not perceived by participants as being reliable in its communicative affordances:

Skype is a platform I find least useful. There are always problems with connection particular when

more than two people want to engage in the conversation. Often it is difficult to hear and there is always someone that is not sure on how to connect. Therefore, I rate Skype as being a difficult platform and avoid using it as a tool unless there is no other option.

Participants perceived connectivist tools used in this study, viz., WhatsApp, Google Drive, and Skype, to have various media, spatial, temporal, navigational, and accessible affordances for the task they were required to complete. These tools provided different affordances needed to complete the task – WhatsApp for alerting members to what was happening, Google Drive for collaborative work on the task, and Skype for verbal conversation and planning regarding the task.

Conclusion

This entry aimed to explore the perceived affordances of connectivist tools for a Higher Education Postgraduate Diploma course. The auto-ethnographic data of the author of this entry corroborate Bryant et al.'s (2014) observation that the use of connectivist tools can make a significant contribution to learning through their affordances which enable social interaction, connectivity, and support of collaborative practices. However, the adoption of connectivist tools may be thwarted on both an institutional and individual level if the perceived affordances of these tools are not made explicit and if personal and professional boundaries become too blurred (Bryant et al. 2014; Madge et al. 2009). The core assignment on this course was designed in such a way as to encourage the creation of a product by the group of higher educators who were part of the interinstitutional PG Dip teaching and learning course through the use of social media platforms such as Google Drive. However, if the affordances of connectivist tools such as WhatsApp, Google Drive, and Skype are to be actualized for educational purposes, they must be accompanied by effectivities of academics and students in terms of their abilities to recognize and use the tools for teaching and learning.

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Agile Methodology

► Agile Methodology in Education of IT Students, Application of

Agile Methodology in Education of IT Students, Application of

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Synonyms

Agile methodology; IT education; Kanban; Project work; Scrum

Introduction

In recent years, the world has become much more complex and unpredictable. A special acronym “VUCA,” meaning “volatile,” “unknown,” “complex,” and “ambiguous,” has even appeared to describe it. The situation changes unexpectedly and rapidly, the crisis becomes the norm of life, and the rate of change inexorably increases. In modern management, the implementation of projects that respond flexibly to the demands of a volatile market is receiving increasing demand.

This VUCA world requires employees able to apply Agile principles to their work. Training in the Agile approach has become common for employees and leaders of large companies but also the governments such as Norway and New Zealand. Agile method education has been introduced at many universities including Cornell University and Northern Arizona universities.

Definition

The word “Agile” has many meanings. The English dictionary definitions include:

- Quick management (Gaponova and Kulin 2016)
- Flexible management (Evseev et al. 2016.
- Active, surviving (Chernykh 2008)
- Agile, lively, fast, moving (Babaev 2016)

By studying the current literature on the Agile topic and opinions of professional experts, it is concluded that there is no precise definition of “Agile” methodology in project management. So it is necessary to consider the most vivid variants of the term “Agile.”

Gaponova and Kulin write that Agile represents flexible management that reacts quickly to changing meso-, macro-, and mega-changes and adjusting economic policy in accordance with changing conditions (Gaponova and Kulin 2016).

Talking about Agile software development, it is a range of different incremental and iterative software engineering methods that are advocated based on an “Agile philosophy” mentioned in the Agile Manifesto (Fowler and Highsmith 2001).

The iterative approach involves splitting the project lifecycle into a series of iterations, each of which resembles a “mini project,” including all phases of the software lifecycle in application to creating smaller fragments of functionality, compared to the project as a whole. The goal of each iteration is to get a working version (release) of the software, including the functionality of all previous and current iterations. The final iteration result contains all the required functionality of the product. Thus, with the completion of each iteration, the product develops incrementally.

Lifecycle of this model allows to classify this model as iterative and in terms of product development – incremental (Defazio et al. 2014).

It is worth noting that Agile software development methods first appeared in the early 1990s, and IT companies were the first to show interest in this methodology. Many of these companies were interested in Agile methods and its application in the companies (Jovanovic et al. 2017).

The use of Agile software development led to changes in the project work in companies, as well as in the results of project implementation, which is a significant advantage of this approach in comparison with traditional (Dingsoyr et al. 2012; Stettina and Hörz 2014).

Considering the various tools of project management, Agile methodology emerged as the first of them, and other tools were formulated on the basis of it.

The most famous for this philosophy was after the adoption of the “Manifesto of a flexible methodology for software development” (Agile Manifesto). This document contains the basic principles that are characteristic of Agile philosophy in project management.

The main ideas of the Agile Manifesto are as follows:

- Individuals and their interactions are more important than processes and tools. In other words, the project team in the Agile philosophy is much more important than the formalization of the processes, because the results of the project depend on it.
- Running software is more important than full documentation. This principle suggests that it is more important to create a working product that fully meets the needs of the client than simply perform a number of works under the contract, not paying attention to the result itself.
- Cooperation with the customer is more important than contractual obligations. It is more important to communicate with the customer and clarify the contentious issues, than work under the contract.
- Responding to change is more important than following a plan. This is also an important principle, because Agile philosophy is a flexible methodology that allows for easy changes to the project, despite formal requirements (documentation, contracts, etc.). During the project, the customer can make adjustments to the product, and the project team accepts these changes.

The Agile Manifesto was written in 2001 even though the start of Agile methods can be traced back to 1957 (Larman and Basili 2003). In the mid-1990s, the so-called “light methods” of project management appeared as an alternative to “heavy methods,” such as the V-model, the cascade model (Waterfall), and various variants of the stage-gate models. Such models were called “heavy” because of a large number of necessary project documentation, a lot of formal control procedures, and

verification of project implementation, which significantly complicated the design work and extended the implementation period. Therefore, the authors of the Agile Manifesto decided to fix the principles of work on Agile flexible methodology in one general document (Grimheden 2013).

Evseev et al. in their article note that Agile defines the basic values, rules, and principles on which flexible project management methodologies are built, such as Scrum, Kanban, Lean, and others. The presented methodologies can be used both together and independently of each other. Refactoring, iteration table, sprints, retrospective, quick meetings, division into roles, etc. are all tools that can be implemented in any project team where the Agile approach will be applied (Evseev et al. 2016).

Speaking about the application of Agile in the IT field, a flexible development methodology is implied as a series of approaches to software development based on the use of iterative development and the dynamic formation of requirements and ensuring their implementation as a result of constant interaction within self-organizing working groups consisting of specialists from different fields (Lopatin 2012; Ildemenov 2016).

Akmaeva et al. argue that the Agile methodology is a set of approaches to software development that is built on the principles of teamwork, speed, lack of formalism in communicating with the customer, and flexibility in changing the initial plan of action (Akmaeva et al. 2017).

Agile is a time-boxed, iterative approach to software delivery that builds software incrementally from the start of the project, instead of trying to deliver it all at once near the end (<http://www.agilenutshell.com/>).

Martin Christopher says that Agile is a system of building work in the company, which makes changes in organizational structures, in information systems, in logistics processes, and in the way of thinking of employees. Flexibility is the main characteristic of such businesses. Indeed, the origin of flexibility as a business concept lies in flexible production systems (FMS) (Christopher 2000).

Another significant definition was given by Fowler and Highsmith that Agile software development is a set of iterative and incremental methods of software development that are promoted on the basis of the “Agile philosophy” captured in Agile Manifesto (Fowler and Highsmith 2001).

Despite the fact that in the main repackaging and re-branding used to be well proven in the development of good software, flexible movement can be considered as an alternative to the so-called traditional methods of software development. Traditional methods focus on pre-planning and strict change management, but flexible methods have been developed for adoption and effective change management (Highsmith and Cockburn 2001).

The Need for Agile Methodologies

The two most popular Agile methods are Extreme Programming (XP) and Scrum (Hamed and Abushama 2013). Scrum is a method focused on the point of view of project management on flexible development (Schwaber and Beedle 2002), appointment of time, continuous tracking of project progress, and customer focus. The XP development method is a set of practices to ensure effective gradual development. In practice, many flexible development projects combine them in two ways (Dikert et al. 2016).

There are several methodologies for project management. The most widely known and long used is the cascade model (waterflow approach). It is defined as the work flow, passing the successive phases of analysis, design, implementation, testing, integration, and support (Evseev et al. 2016).

This model is more suitable for large projects that are performed for a long time with the involvement of a large number of employees of different positions and functions. It is important to note that the distinctive feature of the cascade model is the execution of each next stage after the previous one has been performed.

Consider the main advantages of using the waterflow approach. Such a project is easily controlled by the customer due to the rigid

formalization of all processes, where each type of work is transparent and consistent. In addition, such transparency leads to more cohesive teamwork due to the fact that each team member knows his area of responsibility and the task pool, which also positively affects the success of the whole project. Such rigid management of the project allows you to accurately estimate the cost of the project and each of its individual stages and determine the timing of each task. This allows you to forecast the necessary costs and financial benefits from this project.

Each methodology of project management is not ideal and has its drawbacks. The main negative point in the cascade model is the lack of flexibility when making changes to the project. Hard formalization of all processes does not allow to quickly changing the elements of the project, which negatively affects the time of its implementation. Even the slightest changes require the whole project or part of it to stop before making the necessary changes to the project documentation. Many project management experts criticize this cascading approach for excessively formal project management, which adversely affects the timing of its implementation, the budget spent, and the quality of the finished product (Evseev et al. 2016).

History of Agile Methodologies

Approximately 10–15 years ago in IT sphere, there appeared another methodology of project management – Agile methodology or spiral model.

Initially, it was thought that the way to production flexibility was provided by automation in order to ensure a rapid change and, thus, greater responsiveness to changes in the range or product volume. Later, this idea of production flexibility was expanded in the broader business context, and a concept of flexibility as an organizational orientation emerged (Christopher 2000).

Agile methods were originally intended for usage in small projects with a single team (Boehm and Turner 2005). However, its demonstrated and potential benefits made them attractive

beyond this context, especially for large projects and in large companies. This is despite the fact that they are more difficult to implement in big projects. Compared with small projects that are ideally suited for rapid development, larger ones are characterized by the need for additional coordination. A particular problem with large projects is how to handle coordination between teams. Large-scale flexibility is associated with additional problems in dealing with other organizational units, such as human resources, marketing and sales, as well as product management. In addition, large scale can lead to the fact that users and other interested parties will be removed from the developers. Despite these known problems associated with large-scale flexibility, there is an industry trend toward the introduction of flexible methodologies in general (Dikert et al. 2016).

An important question is raised by many researchers as to what benefits the team or company receives from the use of flexible technologies. According to the 11th Annual State of Agile Survey, the companies get the following benefits from Agile application:

- Ability to manage changing priorities. In today's rapidly changing world, this characteristic is one of the keys for these companies.
- Quickly make changes in the business processes in the company according to the new data from the market. Agile allows flexible companies to remain on the market and be ahead of competitors.
- Increased team productivity.
- Improved project visibility.

Agile methods become the most commonly used in the software industry. Annual surveys have shown that the use of Scrum has increased over the past few years. According to the Annual State of Agile Survey, in 2016, the percentage of respondents' organizations that practice Agile amounted to 94%.

Knowledge of Scrum is critical for most companies, as it emphasizes the importance of team effort and social activity in software development. Scrum is often used in project management

projects and includes monitoring and support, which provides transparency (Mahnic 2011; Coupal and Boechler 2005). This advantages allow the use of Scrum reducing the gap between the skills taught in academic contexts and the requirements imposed on the software industry (Rodriguez et al. 2015).

With the growing popularity of Agile software development methods, the software community has faced a new challenge. Most Agile methods “pay very little attention to overall architectural activity” (Babar 2014). For example, Kent Beck views architecture as emerging and evolving in everyday design (Beck 1999). Kruchten et al. predict that “the software architecture will be recognized as a key basis for Agile software” (Kruchten et al. 2006). The question of how much architectural effort is required in flexible projects was rated as “the second, burning issue facing Agile practices” (Freudenberg and Sharp 2010).

The relationship between Agile methods and the software architecture in education has not been sufficiently studied in the literature. Cleland-Huang et al. represent an approach to the study of software architectures in Agile projects in education (Cleland-Huang et al. 2014). This approach focuses on the design phase of the architecture in Agile projects and, in particular, on the role of stakeholders, but does not affect the actual dynamics of this Agile project (Angelov and Beer 2017).

Angelov and Beer (2017) present an approach to the implementation of software architecture in Agile education projects and share our experience with two successive application approaches. The strategies chosen for the implementation of architectural measures proved to be mostly effective. Using our approach, students perceive the value of architectural actions and view the access as an addition to the Agile software. They appreciate the avant-garde activity in building architecture, although they perceive it as a slight deviation from flexibility. The realism of this approach requires additional attention. It was applied mainly to architecturally savvy software, while in practice, the software often does not understand or appreciate the architecture activities performed in the

projects. In the future work, it is necessary to study the types of problems that an architect and Agile teams face when working with architecturally uncoordinated software and the approaches they can perform to facilitate them (Angelov and Beer 2017).

Teamwork is one of the key competencies that students must acquire to be competitive in the labor market, as enshrined by the European Higher Education Association (EHEA) (Noguera et al. 2018). The ability to work in groups is of particular importance, since today many tasks are too complex and too large to be performed by one person. Many studies show that the use of teamwork in learning increases students’ motivation to gain new knowledge and experience (Laux et al. 2016). Students have to learn to cooperate fruitfully with each other and to independently organize work in group (Miller and Hadwin 2015; Tseng and Yeh 2013).

The flexible methodology of Agile project management is becoming very common in tertiary education. Lecturers advance Agile methodology, especially a scrum in educational process that will allow students to use the gained knowledge in practice in the real companies (Scott et al. 2014).

Many large companies note importance of training in Agile methods at various business schools. The strategy of large companies such as British Telecom and IBM is directed to use of flexible technologies in all business (Grout and Bonham 2012). This is also true of many companies not in the IT sphere who also actively apply Agile principles of work in the business. It is possible to give the Government of Great Britain (the review of the NAO 2012), the US Government (the report of GAO 2012), the banking sector as examples (Sarran 2012), the pharmaceutical industry (Fitzgerald 2012), and many other branches (Cubric 2013).

Agile Methodologies Course Example

Kropp and Meier have conducted survey of 103 students to understand the efforts they spent in projects for project management, programming of a product, and drawing up necessary

documentation (Kropp and Meier 2013). The result of the poll has shown that a lot of time and work has been spent for management and documentation preparation. Also students have noted that during implementation of student's projects, they have gained much more knowledge and competences, than at ordinary lectures that has also positive effect in educational process.

Besides these competences, flexible values which are sounded in the Agile Manifesto (<http://agilemanifesto.org/>) are important. The mutual respect, openness, and courage are examples of such flexible values (Kropp and Meier 2013).

The course on program engineering on Agile methodology which is submitted in the work of Kropp and Meier can be an example of the application of Agile education. This discipline was carried out for students of a bachelor degree and lasted one semester (16 weeks) with a total of 120 h. The number of students was 27 people. Within the course, a 2-h lecture for all students and a program seminar for a half of students were given every week. Work is implied in teams from six to eight people. The complete project of programming Java created with the use of flexible methodologies was the result of the development of a course.

In the part one titled application engineering the practical – at the first two lectures has been given to students' introduction to extreme programming (XP). The extreme programming and Agile Manifesto methods were discussed. In seminars, each student has finished assessment of coding and has received comments.

While the students were working individually or in small groups in part one, part two was different – the Agile game was played in the classroom. The students must be members of a "real" scrum team to really understand how scrum works. Since this is not possible in the classroom, the scrum team was simulated in the student project. The student project purpose was to develop a 2D computer game applying all needed engineering practices. The students worked in four scrum teams of six to eight. Each team was free to decide what kind of computer game they wanted to develop. One student was voted scrum master;

the lecturer was the product owner. The teams completed six 1-week sprints. Every week during the workshops, each team did the sprint planning, sprint review, and retrospective coached by the lecturer. During self-study, the students developed the actual game. In the last week, all the teams could demonstrate a working game.

Agile values (Agile Manifesto) are difficult to teach. The approach in this course was to present to the students that these values are not just something the developers of the Agile Manifesto intended to give lip service to and then forget. They are working values. The Agile value concepts were introduced in the first part. Usage of the values was propagated in the second iteration through means like retrospectives, common code ownership, or pair programming. Many discussions during the lectures and workshops tried to transport that message (Kropp and Meier 2013).

Development of an Agile training course is also important process in the higher education since depends on competently built course knowledge and skills of this approach gained by students.

Ingrid Noguera et al. describe creation process of such subject matter in the work. Two online and three personal meetings have been held for construction of the new training course. An important point is Google Drive usage and the Dropbox instrument for sharing the files in the course of creation of documentation of a new Agile course. After definition of the new scenario, the introduction process has begun in autumn and spring semester of academic year 2015–2016. The new course has been tested during two consecutive semesters. After each iteration, the design was estimated on the basis of notes and opinions of the teacher (collected through two interviews) and opinions of the students (who are brought together through two polls held at the end of both semesters). Based on assessment, minor changes have been applied to design which have been simply directed to providing more accurate recommendations for students (Noguera et al. 2018).

In 2011, in KTH Royal Institute of Technology, Switzerland, it was offered to five student's projects on mechatronics to use a scrum in implementation of projects. 37 students, 5 companies,

and 10 teachers have participated in this experiment. In total, five design teams have been organized. The working product prototype has acted as a result of project work of college teams. The application of an Agile methodology in project work of students teaches bigger flexibility to cope with a difficult task when developing a product in the sphere of mechatronics. Besides, flexible methodologies allow carrying out IT projects quicker and more qualitatively. Universal introduction of an Agile and scrum at the university is complicated by complexity of refusal of the traditional work principles of design team and the fact that mainly flexible methodologies are used when developing IT projects today (Grimheden 2013).

Cubric in the entry gives an example of Hertfordshire Business School where since 2007 the discipline “Flexible project management” within training of masters in the sphere of project management has been entered. The main course objective is providing to students practical experience of application of flexible technologies. Within this discipline to students offered to create the Internet the page on training in flexible approaches, using the Wikipedia platform. In total, the project has included five iterations (sprints), and each sprint lasted 2 weeks. In each design team are cast as follows: one student carries out a role the master’s scrum (scrum master is appointed by other team participants), and the others are performers. The scrum master’s role consists in ensuring effective teamwork, carrying out regular sprints, and preparing reports on the done work at the end of each sprint.

Within the next 3 years, students gave feedback about this course specified by positive sides of discipline – regular and operational feedback about the project implementation, the interest of the teacher in a subject, and a practical orientation. One of course problem is unavailability and inability of some students to work in team that is implied by flexible approaches (Cubric 2013).

Erturk and Mac Callum (2015) have presented in their article interesting ways of flexible technology application in the educational program of IT specialties in a higher educational institution in New Zealand. In the first case it is described how students acquainted with flexible practice within

discipline the system analysis at which more than 30 students studied.

The second research was directed to applying of practice within discipline the user interface where flexible Agile methodology has been used for assessment of course passing.

The main motivation of such experiments is to acquaint students with flexible approaches and to show that they can face them in practice, in the real company. Therefore, it is necessary in advance to study and try to use what will be applied in future work of students.

Therefore, the lecturer used this course as an opportunity to acquaint students with some concepts and approaches of flexible development in branch. The purpose was not in completely to imitate Agile, and it is rather to give to students the chance to see how these methods can be built in system development. The main attention was concentrated on studying and use of the UX/UI methods, while they have also tested how flexible approaches can support its work (Erturk and Mac Callum 2015).

Kamat and Sardessai present the principles to the Agile Manifesto adapted for use for flexible approaches in education in the article. Their option of the principles of this code looks as follows:

- Teachers and students are much more important than administration and infrastructure.
- The competence of the team and their cooperation are more important than observance of regulations and the competition.
- The involvement into work and competitiveness of a product are more important than the plan of work and the set indicators.
- The relation to the project and skills of training are more important than abilities and education (academic degrees).

The flexible manifesto in education can be applied in all main spheres of educational activity with assistance of ICT. It is expedient to teach some disciplines to students of different specialties. For example, the course on geometrical modeling could be taught in common in the field of computer sciences, mathematics, and

mechanical engineering faculty. All cooperation has to be facilitated by means of a learning management system (LMS). At the same time, students can find all training materials on available free resources in the Internet that unifies a discipline course. It is promoted by appearance of the Web 2.0. In that case, teachers can spend more time for practice.

Also Kamat and Sardessai declare in their article that it is necessary to approach modern information technologies in the training course, for instance, to suggest students to pass the small test on the passable material on their phones at the beginning of the occupation. Thereby, the student's motivation to digestion of material increases. In general, authors say that it is important to transfer all system of the higher education to the flexible half-courses and to take modern IT tools (Kamat and Sardessai 2012).

Pozenel and Mahnic describe how the checklist was used for design of empirical studies with students (ESWS) at computer and information sciences faculty at the University of Ljubljana, Slovenia, for the purpose of assessment of two most widespread methods of flexible assessment, that is, planning poker (PP) and team estimation game (TEG). The research is conducted within a training course on the development of the software in which students have to work in teams to develop the project, strictly following Scrum.

The capstone course at the University of Ljubljana teaches students to the software flexible development, in particular scrum, on the basis of practical command projects. The course lasts 15 weeks and is accepted by student's information scientists in the last (sixth) semester. Students have to work in groups to develop the real project on the basis of requirements of the users provided by the expert of the domain playing a role of the product owner.

The course design is based on scrum structure and consists of four sprints. The first sprint (which is also called by Sprint 0) lasts 3 weeks and serves as preparatory sprint prior to the project beginning. Other part of a course is divided into three regular sprinters of scrum sprint (Sprint 1, Sprint 2, and Sprint 3), each of which lasts 4 weeks.

During Sprint 0, there take place official lectures to teach students of scrum and how to apply the user stories to the requirement specification and project planning. These 3 weeks are also used for acquaintance of students with the initial product lag containing a set of priority user stories for the project which they are going to develop. At the end of Sprint 0, each team estimates the efforts necessary for realization of each history of users and prepares the plan of release.

Sprinters 1, 2, and 3 are regular sprints which have identical structure. Each sprint begins with a meeting on planning of sprint in which students report about the content of the following iteration with the product owner and develop the initial sprint backlog version. During the sprint, every team should get together at meetings of daily scrum regularly and to support their lag from sprint, while at the end of each sprint, reviews of parley and retrospective meetings of sprint are held. At a general appointment, students present the results to the heads, and at a retrospective meeting, students and heads forgather to discuss development process in the previous sprint in which suggestions for improvement in the following are offered (Pozenel and Mahnic 2016).

If to speak about Russia, then there is no practice of application of Agile in the university environment now. Certainly, not all problems in education can be solved with the help of flexible methodologies. For example, at the university, it is possible to build work of scientific and educational groups or design and educational groups; it is possible by means of methodology Agile. Also flexible methodologies perfectly are suitable for a design seminar where students work on the projects. An important part of educational process of all students is preparation course and theses, work which can also be built with use of collaborative technologies. Also flexible methodologies can increase productivity of work on applied projects of external customers at the university thanks to harmonious work of team and continuous contact with the customer.

It is important to remember the organization of scientific activity at the university. Flexible technologies can be applied at the organization of work on preparation of the application for a

grant, when carrying out joint scientific research, including with foreign colleagues. Also Agile methodology perfectly fits into the organization of work on writing of joint articles, monographs, and textbooks in co-authorship.

Impact of Agile Methodologies in the Classroom

The course to an Agile at the university especially on IT specialties is obligatory discipline in the modern world. Before development of a new Agile course for program engineering, it is important to define competences which need to be developed at students in the course of studying of a course. Such competences can be divided into three categories.

First of all, it is technical skills. Their development forms a basis for development of the high-quality software. Engineering practitioners who especially carefully accustom to extreme programming are also important and include modular testing, clean coding, test development, collective possession of a code, and others. Engineering practitioners are competences which accustom everyone the person individually.

Also important competences are flexible management methods. Agile project management defines as projects on flexible technology are formed and started. Flexible methods of management include iterative planning, the short release periods, strong participation of clients, and highly intellectual and motivated teams. Management social competences are extremely important in the process of Agile methods development to form team and adjust work.

Summary

The cases cited in the entry show the applicability of the methodology in the educational environment and not only in the teaching of computer technologies.

Using Agile tools allows students to save time on developing a new product and improve

interaction between team members, which leads to increased productivity.

Thus, the methodology should be shifted not only to teaching computer sciences but also to other educational programs, where the design type of instruction is applied.

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Agile Methods and Team Work in IT Education

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Synonyms

Collaborative practices; Project-based learning;
Software development

Software Engineering and Information Technology Curricula

Information technology and software engineering education curricula incorporate training in programming and computer technologies, as well as basic science skills. As information technology is always applied in organizations, skills related to organizational understanding, business and interpersonal relationships are gaining more emphasis when the extent of systems grows. Competencies required from software developers are getting wider; developers are expected to understand the lifecycle of the products from early planning to design, implementation, and maintenance. The concept of systems development life cycle was introduced around 50 years ago, and since then information systems have evolved from individual entities to interconnected webs of technologies, data, and software. Understanding current technological and information environments is an enormous task that maybe no one fully masters any more. Educational institutions strive to provide skills and tools that help in this constantly growing and evolving challenge.

Although education standards vary from country to country, the international and global character of software development enforces certain amount of unity in training. Same tools and programming languages are used all over the world, and many large systems development projects are divided between many locations and countries at the same time. Even though there are some

systematic differences in the working habits and organization of the work between cultural areas, global requirements for collaboration challenge them. Outsourcing to distant countries has become standard in software work, and differences are doomed to narrow. Organizations with low hierarchy that allow employees a good degree of self-determination will be best candidates to apply agile methods, which are becoming the new standard of software work.

Competence Requirements from Industry

What are the essential industry skills in software engineering or information technology? The UNESCO global report on the status of engineering 2010 discusses engineering education, which has developed worldwide towards similar overall practices (UNESCO 2010). According to the report, there seems to be a wide consensus on main goals of engineering education.

Accreditation bodies define information technology and software engineering competences broadly to accommodate the variation of educational institutions and programs. For example, the list of goals by ABET in the USA remains the same in the last decade (<http://www.abet.org>). ABET includes in the student outcome requirements for any engineering program general science and technology skills, research skills for conducting and analyzing experiments and data, and an ability to formulate engineering problems. Moreover, engineers need to be able to consider also constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability, and to act ethically. Particular working life skills are listed as an ability to function on multidisciplinary teams, and to communicate effectively. The UNESCO report on engineering mentions similar capabilities, referring to a many other organizations and accreditation bodies (UNESCO 2010). The question remains, however, how these goals are attained within various educational systems.

Dialogue with companies has revealed that ICT education had failed to fully respond to the current requirements in the software industry despite existing standards (Holvikivi et al. 2017). Demands from companies increasingly

stress capabilities for collaboration, efficient team work, and professional communication. Moreover, feedback from software industry has confirmed some of the points previously mentioned, such as the ability to function on multidisciplinary teams and the ability to communicate effectively are needed, but there is also need for negotiation skills, and, specifically, a need to understand development processes. The fast changes in development practices need particular attention.

Teamwork and Group Processes

Groups play a critical role in people's lives, and in particular, in contemporary business environments, teams occupy a central role. Teamwork and groups are mainly studied by social and organizational psychology. In his review of current status of research in group processes, Levine (2013) emphasized that the amount of accumulated research is enormous, and the interest has not shown signs of decline because of the great importance of social aspects of group processes in organizations. Some of the most important findings regarding group processes that are relevant to student teamwork, agile development practices, and education are presented below.

Perhaps the most essential research finding is the importance of mutual trust in the team. Groups perform better when their members feel accepted and comfortable in the group. Certain personal factors influence this, namely interpersonal attraction, as well as individual characteristics of group members such as openness to experience. The degree to which the rest of a group agrees with each member about who he or she really is has an impact on the feeling of comfort. Moreover, mutual support and leadership improves group cohesion. The leader of the group has a crucial role in taking a visionary position and inspiring people to follow. Additionally, group performance is affected by a number of task related factors, such as the complexity or difficulty of the tasks, routineness, or autonomy.

Creative groups need to aim at internal synergy and to overcome the factors related to production loss in groups such as social loafing, evaluation

apprehension, production blocking, and downward comparison. One of the means is to ensure that group members are held accountable for their individual contributions to the group. Moreover, group members should feel free to express their ideas as they occur without fear of others' criticisms, and members must be motivated to process information from other members. Diversity within group usually is beneficial for its creativity. Factors which enhance the benefits of diversity are a generally supportive social context and a longer time working together as a team. Research has proven effectively that successful real-world collaborative groups have a common vision and set of values. When the composition of a group is changing in one way or another, even when the members remain the same, it requires renegotiation of the interpersonal relations from time to time.

Student Teamwork

In case of student project groups, the composition of the group is often one-time only, and the members might not know each other previously. To ensure that a transformational leadership and mutual trust in the team are formed, instructors have to support the teams in the beginning. Establishing a leadership position and gaining authority in a team tends to be difficult for students in a peer relationship. Even later, teams require monitoring and facilitation that prevents social loafing, free-riding, and negative interactions within the team. One way to encourage equal contribution to the projects is to organize a mutual evaluation at the end of the project where students are individually requested to indicate how much each team member contributed to the project.

Teamwork and project work are more challenging to evaluate fairly than individual deliverables. Larger teams such as six or seven students are more problematic in this respect. Most often teams of four are the ideal solution also for team efficiency. Moreover, a regular presence of teachers in the classroom gives them an understanding of each student's skills. Also, virtual environments such as Trello and GitHub follow individual contributions.

Teacher Competences in Team Teaching

Multidisciplinary courses built around real-world problems provide one possible way of helping students to improve their communication and group working skills in an environment resembling actual work life situations. These kinds of courses are by definition being designed, conducted, and evaluated by a teacher team as opposed to a single subject matter teacher. At many universities, teachers are used to being the only teacher responsible for the course. Teaching staff with industry experience has learnt teamwork in practice, but for purely academic staff, the change required to work efficiently in a team of colleagues might be challenging. This change is profound as it is not just a method or single skill, but it actually changes the whole culture of teaching. Actually, this new challenge for teachers to be able to work productively in collaborative teams is similar to the requirement set by the changed working life for their students. It could be considered a legitimate requirement for teachers to follow the same practices they expect from their students (Vesikivi et al. 2018). The method requires that teachers have an open mind and are ready to face uncertainty. Teachers need to have enough professional experience and confidence when they start collaboration in this format.

Collaborative Problem-Solving and Project-Based Learning

Collaborative problem-solving and project-based learning are considered central methods to educate present day engineering students, because they simulate challenges that the students will face in professional work, such as open-ended assignments, uncertainty, and coordination of collaborative efforts. Numerous implementations of project-based learning have been reported in various countries in recent years. Even though the theoretical backgrounds of these efforts differ, the practical implementation usually follows similar patterns on applying a project development cycle to course work and concentrating on the problem and its solution instead of listed curriculum items (contents, skills, competences).

One of the well-known systematic efforts towards project-based learning is the global CDIO initiative that has united a number of engineering institutions around a common curriculum structure worldwide (Crawley et al. 2007). Another global model which extends beyond engineering to other academic fields is led by the Aalborg University in Denmark. Edström and Kolmos (2014) compared these two models and found them to be mutually complementary rather than competing. The CDIO model includes one project in each academic year, whereas the PjBL model followed in Aalborg is totally based on thematic project courses. Numerous other successful implementations of project-based learning methods have been reported in various countries in recent years, building a large body of evidence for their favor.

In the CDIO syllabus, personal, professional, and interpersonal skills include engineering reasoning and problem-solving, experimentation and knowledge discovery, system thinking, multidisciplinary teamwork, and communication (Crawley et al. 2007). When the learning is organized between members of a collaborative community combining theory, creativity, progressive inquiry, and practice, it profoundly develops student understanding (Lakkala 2010).

History of Systems Development Methods

With the increasing capacity of computer hardware, and development of high-level programming languages, application size grew fast in the 1960s. The maintenance and control of new large software modules required software development methods that were later called software development life cycle (SDLC) or systems analysis methods. The first methods were built for managing large mainframe software applications such as statistical, insurance, and banking systems, not to forget military applications. The software engineering methods emphasized structural, controlled processes, and extensive documentation, and were coupled with project management methods. The development work

was divided into distinct phases, which is referred to as the waterfall model: defining business requirements, system analysis, design, coding, testing and evaluation, implementation, and training and maintenance. Each phase has fixed deliverables, milestones, and measures that mark its completion and move to the next phase (Encyclopedia of software engineering 2002).

The basic waterfall model led to development of CASE (computer-aided software engineering) tools in the 1970s to smoothen the development work, and methodologies such as UML in the 1990s, the visualized unified model that is tied with object-oriented programming. However, when systems became even more complex in networked environments, and particularly the new application types appeared in the internet, the waterfall model was used in more creative and flexible ways, including prototyping, iterative, and incremental development.

Agile and Scrum

Software engineering has encountered methodological crisis in 1960s and again in 1990s because of the complexity and long development time of large applications. In 1994, it was estimated that over 80% of the software projects encountered delays and exceeded their budgets. The Agile Manifesto in 2001 (<http://agilemanifesto.org/>) was a culmination of the frustration on heavy long-lasting projects. It condensed the alternative views into a list of 12 principles:

1. Customer satisfaction by early and continuous delivery of valuable software
2. Welcome changing requirements, even in late development
3. Working software is delivered frequently (weeks rather than months)
4. Close, daily cooperation between business people and developers
5. Projects are built around motivated individuals, who should be trusted
6. Face-to-face conversation is the best form of communication (co-location)
7. Working software is the primary measure of progress

8. Sustainable development, able to maintain a constant pace
9. Continuous attention to technical excellence and good design
10. Simplicity – the art of maximizing the amount of work not done – is essential
11. Best architectures, requirements, and designs emerge from self-organizing teams
12. Regularly, the team reflects on how to become more effective, and adjusts accordingly

Agile methods are based on four broad values derived from the Agile Manifesto: individuals and interactions, customer collaboration, working software, and response to change. These values are common to all major forms of agile methods such as Scrum, Extreme Programming, Lean Software Development, and Crystal. The agile way of working includes short development cycles that are called sprints and constant interaction between the development team and the customer. It is best suited for web projects where requirements tend to change quickly, and goals are not very clear in the beginning. Therefore, agile methods were first adopted by smaller companies with smaller projects. However, currently, even the largest software and ICT companies, such as Accenture, Microsoft, Nokia, and SAP, claim to apply agile practices in their work.

The various methods to apply agile development typically include sprints that last a week or two and scrum as project management method. In scrum, small stand-up meetings are held daily to check the current progress and assign new tasks. Moreover, scrum includes a few roles such as scrum master and product owner. A sprint has a task list from where team members pick their tasks after they have finished the previous one. After the sprint cycle, there should be a product prototype that can be evaluated, and further decisions made based on the delivery. Short cycles allow changes in requirements and close monitoring of costs and other resource use.

Lean and Kanban

Lean manufacturing and kanban were developed in Japan for Toyota, and their idea is to simplify manufacturing process by eliminating all waste,

minimizing inventory and process time. In software development, kanban cards are used for tasks, and they will contain a backlog for the project. Use of kanban cards has exploded in all business areas with the availability of simple online products such as Trello or Asana.

Experiences Form Agile Courses

Agile software development has replaced former, highly systematic project management practices in many areas of the software industry. Software development has changed drastically during the last decades. Individual coding or testing in large projects still exist, but most developers have to be able to co-operate in diverse teams and to apply flexible working methods. Many studies have shown that agile methods are already mainstream in the industry (Kropp et al. 2016). However, the incorporation of the tremendous changes in development practices has entered academic education rather slowly.

First efforts to include agile methods to higher education were made more than a decade ago, and currently, separate courses on agile development are widely offered as part of software engineering curricula (ibid 2016, Mahnic 2012). However, actual use of agile methods as educational practice is less common even though a widespread use is presumably on the brink of breakthrough. Agile development can be applied in many kinds of project-based learning courses by replacing traditional project management with flexible practices and sprints, and by replacing formal meetings with scrum meetings. Compared to traditional project management methods, this way allows more development cycles and therefore enables the completion of a functional prototype during an academic module.

The literature on agile methods in education presents largely three different ways to approach the subject. First, as any other subject, project management can be lectured and knowledge tested through examinations. Nevertheless, this method does not address the development of interpersonal or organizational skills.

Secondly, agile methods can be introduced through a project course, where they are practiced in an application development project. There are many examples of innovation and multinational application development projects, where the agile approach and teamwork function as a backbone, even though not necessarily explicitly expressed. The EU has sponsored Erasmus intensive programs that include universities from several countries and require a preparation phase over distant education tools. In this kind of international efforts, where virtual learning environments are an essential part of the course, students and teaching staff from various universities need to adapt to changing and unexpected learning settings.

Positive experiences have been reported particularly from capstone courses where students are assumed to have already strong technical skills and involvement of real customers is possible (Mahnic 2012). Moreover, agile working methods have been studied in multicultural groups, and in courses on software business, reporting promising outcomes. However, it remains unclear whether negative cases have been reported to the same extent as positive outcomes.

A quick introduction to agile, user centered way of developing product ideas is presented by Google Ventures Sprint (<http://gv.com/sprint>). Even though it is mainly designed and applied for real business settings, the 1-week framework makes it a suitable way to introduce the main ideas to a student group. Because it is very much hands-on, practice centered, it gives a quick immersion to creative IT work.

The third, most immersive method extends beyond agile courses, where agile work has been expanded to the entire curriculum. Agile approach is more than a subject of study; instead, the methods in course design and implementation are based on agile ideas. In this approach, the schedules of modules are not defined in strict detail in advance; instead, the planning is flexible and done in small increments during the implementation (Holvikivi and Hjort 2018).

Case Example: Simulated Work Placement

Metropolia University of Applied Sciences offers a bachelor of engineering degree in information

technology. Part of the degree is a 3 month internship in a company. Sometimes students fail to find a real employer for their work placement. A simulated workplace environment was created to give students chance to practice internship in this kind of situation. Fourteen students participated working full time as interns in a designated office space inside the school building during 3 months. They received an order from a publishing company that wanted to explore alternatives for a new product. The work was organized as an agile project, which emulated real workplace conditions. The project group held regular scrum meetings every morning where teachers participated as needed. In a scrum meeting, all participants stand up and explain briefly what they have done since the last meeting, what they intend to do next, and what kinds of problems they face.

A working life experience should teach project management and team working skills in addition to technical skills. Because of a real customer, students started understanding what making a commercial product entails, and how user needs are incorporated in design. The scrum development project was a new method for the participants. In the beginning, the group held scrum meetings every day in the morning. First, teachers were involved to show the method, set up timesheets for work, and comment on student achievements and plans. Three weeks later, teachers let the team divide into technical and user interface groups that were self-regulating. Students were allowed to decide how often they need scrum meetings and stopped holding them daily. Soon they noticed that having fewer meetings did not facilitate the process (Holvikivi and Hjort 2018).

Case Example: Software Engineering BSc Curriculum

The software engineering curriculum for bachelor of science in the Metropolia University of Applied Sciences in Finland went through a fundamental change in 2014 (Holvikivi and Hjort 2018). Project-based methods were included into most modules in the new curriculum. Additionally, the concepts of progressive inquiry and problem-based learning were applied in course design. It

was assumed that it would be most efficient to start with open-ended problems immediately at the beginning of studies. Moreover, participatory online learning environments were used to support the learner's development of understanding through collaborative construction of a shared product (Lakkala 2010).

The first study year was divided into four successive 15 ECTS modules 8 weeks each. Each module had a theme that introduced the different IT subjects students could major in: networks, media and web-development, electronic devices, and software engineering. The project in each module was supported by a varying amount of basic and theoretical studies such as mathematics and physics.

In an integrated module, all professional and language content (communication skills) was integrated apart from the separate science classes. The teachers collaborated both in theoretical subjects and project work. Deliverables such as presentations and project documentation were assessed both on substance and communication aspects. Some types of lessons with practice usually had more than one teacher present. Also during student team presentations most teachers attended, gave feedback and evaluated deliverables together.

The integrated modules that applied an agile approach were Orientation and Games (programming) in the first year, Application Development Methods in the second year, and Software Business Start-up in the third year. They were largely similar in design, lead by nearly the same teacher teams who applied agile practices in the planning of instruction.

The Games module was actually an introduction to Java programming. In the beginning of the module, students attended some lectures in programming and completed a large number of programming assignments in a MOOC setting. The MOOC (massive open online course) was provided by the University of Helsinki. Additionally, students completed a game project during those 8 weeks. After the setup of teams in the second week, teams held weekly scrum meetings, and they were required to use kanban (Trello) for task management.

The Application Development Methods module in the second year consisted of a mix of Finnish and international software engineering students. As the name implies, the module concentrated on software project management skills. The lectures covered some conventional project management, a number of development tools, and user-centered design. The technical skills included setting up a Java server, creating a responsive client-side, using GitHub and REST API, and usability testing tools. Other methods that the students were already familiar with included Trello and scrum meetings. Additionally, students used a variety of free online tools that they chose themselves. The composition of teams was constrained in a way that single-nationality teams were not allowed. Diverse teams tend to be more creative, and on the other hand, multicultural teams offer important skills for the future of international students.

The Software Business Start-up module was conducted in the beginning of the third study year. The idea of the module was to practice business skills by creating a mock start-up and developing a product prototype. The module built on the skills that had been acquired earlier including Git version control, weekly scrum meetings, voluntary use of kanban and other agile tools. Some new technical skills were introduced, namely the so-called MEAN stack that contains node.js and noSQL databases. Student teams were allowed to assemble freely, but the team size was limited to four. Very obviously, student ability to tolerate uncertainty had increased from one module to the next. In the second implementation, creativity and innovation were practiced during 1 week using the Google Ventures sprint model. The generation and development of product ideas was unprecedented in the classroom.

Certain positive outcomes were obvious, such as high student satisfaction and good retention rate (Holvikivi et al. 2017). The change from large study groups, separate lectures and laboratories into smaller, tightly knit groups seemed to have been a decisive factor in improving the results in the first years. Belonging into a group and working in teams was a simple way to enhance commitment to studies and overall

feeling of belonging, for students from diverse backgrounds in particular.

Nevertheless, the results of this case extend beyond agile courses, as agile work has been expanded to the entire curriculum. Not only the subject of study but also the methods of teachers in course design and implementation have applied agile ideas. The modules were not defined in much detail in advance; instead, the planning was flexible and done in small increments during the implementation. In particular, in case of heterogeneous student groups, this allowed more freedom in the realization.

Conclusion

As understanding the development process becomes more important for software developers, skills that help to master the process have to be included in software engineering curricula. New ways of teaching bring advantages to the institutions in terms of graduations and good results for courses as well, and enrich the work of faculty. Agile development is an exciting new avenue, which is not only embraced by the software industry but also applied to project work in other areas of business.

Cross-References

- ▶ [Agile Methodology in Education of IT Students, Application of](#)
- ▶ [Mobile Computing and Mobile Learning](#)
- ▶ [Software Development Processes Designed for First Year Computing Undergraduates](#)
- ▶ [Teaching Software Design Techniques in University Courses](#)

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Alerting Devices

- ▶ [Assisting People Who Are Deaf or Hard of Hearing Through Technology](#)

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- ▶ [Design in K-5 Programming Projects, Role of](#)

Algorithmic Language

- ▶ [Programming Language Selection for University Courses](#)
- ▶ [Teaching Computer Languages in Universities](#)

Algorithmic Thinking in Primary Schools

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Technological advances have changed the ways we work, learn, and play. For today's students to take full advantage of the opportunities these technologies afford, a set of ways of thinking, that mirror how computers function, are increasingly pervasive in schools. These include a thinking skill called algorithmic thinking that can be seen to be comprised of four key areas:

- Design thinking
- Decomposition
- Pattern recognition
- Abstraction

These four skills are used in schools to engage learners in problem-solving, critical thinking, and collaboration. They offer opportunities for learning across the curriculum. Algorithmic thinking activities can be seen in written maths problems, in historical research, in text analysis, and in the evaluation of art products. Current research suggests that engaging students in algorithmic thinking in their early schooling can open doors for them as adults entering the workplace (Deloitte Access Economics 2017).

As technological change continues to infiltrate our homes and schools, it has become clear that school curricula documents must reflect the society in which they are used. Curriculum writers are therefore seeking to engage students in the key thinking and practical skills that might enable their full engagement in the world of work and life beyond schools.

What Is Algorithmic Thinking and Where Did It Come From?

With its origins in mathematics, algorithmic thinking refers to logical, sequenced processes

that together create a desired outcome. Algorithmic thinking, in relation to technologies, has developed concurrently with computer programming and the microprocessor. At its simplest level, algorithmic thinking can be seen as $2 + 2 = 4$.

Although sometimes used interchangeably with the term computational thinking, algorithmic thinking is focused more on the design stage of problem-solving. Whereas, “In computational thinking, the focus is on the data and the interpretation of the data, and the algorithms are just tools available to help with that” (Gas Station Without Pumps 2010).

Algorithms, of the type discussed here, first came to the fore with computer programming breakthroughs of the 1940s. Indeed, algorithmic, mathematical, thinking can be seen to exist in the code-cracking histories of World War Two and Turing’s Enigma decryption machine.

A computer algorithm is a set of instructions that interact in a sequence to produce a desired outcome. An example is the “home” button on a mobile tablet or smartphone. When this button is clicked, it triggers a set of algorithms to complete the task, in this case, to display the home page on a device’s screen. Understanding that logic and sequencing underpin technology, and that errors or challenges with technology might be solved through a logical sequenced approach, are skills needed in a wide range of industries.

In Israel, England, the USA, and France, algorithmic thinking is already part of many school curricula documents (Deloitte Access Economics 2017).

In Israel, algorithmic thinking is presented as a core skill for successful twenty-first century life; in England, these skills are embedded with a curriculum focused on coding and computer programming.

No longer seen to be a skill unique to computer programmers, algorithmic thinking has become a new type of language and literacy in today’s world. Solving a problem using digital resources and designing logical models for implementing solutions are important skills for

today’s students. While a number of definitions of algorithmic thinking are available, there are four main aspects that appear common. These are explored below.

Abstraction

This aspect of algorithmic thinking focuses on making meaning from data. Students create rules about the data they have uncovered and view the broader implications of it. This might be understanding how data fits into a larger context or to reduce a complex idea to its fundamental concepts.

Systems Thinking

Many aspects of problem-solving and computing require an ability to see the complexity of the systems within which they are embedded. Systems thinking seek to understand the interactions of people, places, objects, or ideas within a system. In a school setting, this might be exploring how predators and prey interact and impact on each other within a microcosm.

Pattern Recognition

Beginning from an early age, students are often asked to engage with pattern-making and identification. With changing demands in the workplace, these patterning skills have increased in significance. Computer programmers use patterns to simplify and replicate basic commands. Students develop patterning skills to make sense of data and to identify inconsistencies from a high-level perspective. Making and exploring patterns can help students to make sense of large sets of data and can reinforce ideas of abstraction.

Decomposition

Sometimes called “factoring,” these skills see students break large sets of data or problems into their composite parts. This connects with the ideas of systems thinking as students compartmentalize problems in order to make better sense of possible solutions. When students are able to break large problems into smaller parts, they can more easily understand the nature of complex problems or ideas.

Changing Workforce Demands

Today's workforce is increasingly engaging with digital technologies, whether that is through email, digital databases or more recently, with virtual or augmented reality. The concept of work itself is also changing with one in three US workers now identifying as a freelance worker (Weber 2014) and one in four hoping to secure new employment in the next year just to "do something different" (Weber 2014).

These should be seen as opportunities for engaging students in new and innovative learning practices, after all, today's primary school students will enter the workforce in the 2020s and 2030s. It is likely that the workforce will be even more digitally, virtual and globally focused than it is already.

With scope for such large changes, it should be asked how teachers can possibly prepare students. If we do not know what social and global changes might occur, how can we teach students to engage with them? This is a question that has been raised by educational leaders and organizations globally.

One answer has come to the fore: prepare students not to use today's technologies but instead to learn how to learn. Developing the skills to learn is seen to be a way to future-proof the learning of students, who are hoped to leave schooling with transferable and flexible skills that may support them in their adult lives.

This focus on the future needs of students in the workforce has framed educational curricular such as the Australian Curriculum (Australian Curriculum Assessment Reporting Authority 2016), the National Curriculum for England (Government Digital Service, UK 2014), and the Israeli higher education program, Ghavim (2017).

New Curriculum Demands

The Australian Curriculum is the newest of these curricula and seeks to engage students in developing core computing skills from ages 5–16. Beginning in the early years of schooling, students are asked to identify patterns and exploring basic algorithms through step-by-step written

activities. These activities might include following or recording a recipe or creating treasure maps with instructions for others to follow.

The Australian Curriculum is designed to engage students in specific thinking skills. Problem-solving, creativity, and collaboration are core foci in the Australian Curriculum and by giving these areas greater prominence, there is an expectation that teachers will place a greater emphasis on helping students develop the so-called "21st century skills" in addition to content related to the various disciplinary areas. As students develop skills, they may begin to design and implement more complex algorithms that leverage technologies in reaching a solution.

Reinforcing the notion of the Australian curriculum as a thinking curriculum is the statement that up to 50% of the curriculum can be completed offline, without the use of computer technologies. Offline learning activities can be effectively used to reinforce algorithmic thinking and might include designing a board game for others to play, finding errors in a list of instructions, or identifying algorithms used in the real world.

With changing curriculum demands in a number of countries worldwide, it is important to restate that the aim of these documents is rarely to produce a generation of computer programmers. With increasing global challenges, such as climate change, unstable political environments, and catastrophic weather events, there is a growing need for individuals who can analyze, decompose, reflect on, and design solutions. The Australian Curriculum frames this interpretation of curriculum in saying, "The curriculum is designed so that students will develop and use increasingly sophisticated computational thinking skills, and processes, techniques and digital systems to create solutions to address specific problems, opportunities or needs" (Australian Curriculum Assessment Reporting Authority 2016).

This curriculum positions the skills that it seeks to develop in students as "... develop[ing] and employ[in] strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test

solutions (Australian Curriculum Assessment Reporting Authority 2016).”

It is pertinent to note that many teachers already engage students in developing these skills in classrooms around the world. These teaching strategies are sometimes called inquiry learning, activity-based learning, or problem-based learning. However, today’s curriculum demands ask teachers to make visible the affordances of technologies in solving complex, open-ended problems. Teachers are now asked to highlight the specific thinking skills that students are using and seek to engage them in reporting on their learning strategies as they solve problems.

Previously, teachers might have asked students to create a paper graph to record the passing traffic outside the school, and then analyze the data to inform an appeal to the local roads authority. New curricular demands would see students making informed choices about which resources and technologies they might use to record passing traffic. These might include developing an app to record traffic that students could use on computer tablets, as they left school each day, or mounting a camera by the school gate that has been programmed to take photographs at designated intervals.

Students might then use the algorithmic thinking skills of abstraction, decomposition, and systems thinking to make an informed case for solving the problem of increased traffic at certain times of day. They might implement, then review, their solution and use pattern recognition strategies to interpret the data they gather.

Although, in these two examples, students are working to solve a similar problem, it is clear that the development of algorithmic thinking skills separates the learning experiences. With a focus on visible and strategic thinking skills, students can engage in more complex, collaborative, and real-world problem-solving.

Beginning to Think Algorithmically

There are a number of online resources available to engage with algorithmic thinking skills. A number of these focus on the development of

computer coding skills. Coding, or programming, can be seen as the newest component of curriculum documents. These skills, therefore, represent the most novel aspects of the curriculum for teachers and learners, and are often promoted as an entry point for beginner learners.

An online search will provide a range of beginners’ guides to computer coding that will introduce concepts of algorithmic thinking. An American not-for-profit organization, called Hour of Code (<https://hourofcode.com>), is one of the most popular and prominent websites for beginners in this area. The Hour of Code website provides free narrated, video courses in basic coding, that walk the learner through developing and implementing computer programs using a “drag and drop” interface. As this suggests, the learner drags coding “blocks” across the screen. By connecting blocks together, a computer code is developed that can then be “run” to complete a basic task. An example might be designing a snowflake by dragging a sequence of codes together that use forwards, backwards, left, and right “blocks.” When the learner clicks on “run,” the code is executed and any problems or errors are revealed.

Drag and drop coding is used in a range of softwares that are freely available as online, web-based resources and as smart device apps.

Algorithmic thinking invites learners to engage in deep thinking, in rationale, sequential processes, and in solution-testing and review. Learners who develop these skills may have increased opportunities in a wide range of career fields beyond school.

Global Educational Changes

There has been a steep increase in the language of computing and computers since the year 2000. Words such as Blog, Wiki, Upload, Download, Coding, and Apps have become part of the common language of society. This is true, too, in schools where computer vocabulary continues to grow as technology changes. These swift language developments can be seen to be indicative of the pace of change in the world and the classroom.

Many teachers around the world now work in Internet-connected classrooms and schools. These teachers can now engage with students online, to support and grow their learning, use interactive resources and virtual reality to bring the world into the classroom and even solve real problems with digital solutions.

As governments around the world seek to align their curricula to shifting needs of their societies, the significance of a set of skills called “algorithmic thinking” increases. It is of note, however, these documents do not seek to develop a generation of computer programmers.

While this shift in curriculum focus can be seen to be driven by society at large, there is no expectation that every child should become a computer technician, programmer, or developer. In fact, the inclusion of algorithmic thinking in schools seeks to broaden student’s opportunities, not narrow them.

Understanding the skills of algorithmic thinking, drawing on its background in mathematics and the first computers, provides insight into how digital technologies work.

This is then can create endless possibilities for innovative, perhaps entrepreneurial, skills to be developed. The 21st century skills provide unique learning experiences that teach students how to

learn in the ever-changing technology-enhanced world they will enter after school.

Take the example of a group of 10-year-old students in a rural primary school in Australia (Table 1). These students are aware of a problem in their wider community: ridesharing services are difficult to arrange and access, meaning a number of students each day are unable to get to school.

These students worked through the four aspects of algorithmic thinking to better understand the challenges of solving the problem. The table above shares the thinking of the students as they moved towards a solution.

Working through this process has helped the students develop a proposed solution: a giant map of the routes parents drive to get to school. These students might need to further investigate the problem. How can a giant map at school help them when they are at home? How could they make the map reflect last minute changes to driving routes, due to weather, cattle, accidents, and so on?

This could lead students to develop a GPS tracking app that parents could use as they drive school. This would not only go towards solving the problem but would also provide ongoing algorithmic thinking opportunities as they develop, trial, review, and maintain their new ridesharing system.

Algorithmic Thinking in Primary Schools, Table 1 Components of algorithmic thinking

Aspect of AT	Key questions	Students’ responses
Design thinking	What is happening here? Why is ridesharing hard to arrange? Which part of the “system” (in this case, the arranging of ridesharing) is causing the problem? How does each part inform the other?	We don’t always know who needs a ride When parents are unavailable at the last minute, we don’t know who could offer a ride We live far away and we could get a ride to the main road, but we don’t know when people are driving past
Decomposition	Where are the main points of challenge? Which parts work well?	Contacting people driving past is difficult. Last minute changes are hard. There are people to drive us – but we can’t always find them!
Pattern recognition	What patterns might help you solve this problem? What do you need to know?	We need to know the routes that people drive so we can find a lift to school We could ask people to map their routes to school and share it with us
Abstraction	How can we summarize the data? What should we look for in the data? How can this data help us solve the problem?	We need to collate all the maps onto one big map so we can see where people drive and whether we can find a lift to school

Using Algorithmic Thinking to Solve Problems in Primary Schools

This section presents examples of algorithmic thinking in action. These examples are framed as learning activities across the three main stages of primary schooling: early years, middle years, and senior years. Students are supported to develop increasingly complex algorithmic thinking skills as they progress through primary school. These critical skills are seen to be imperative for all students from the beginning of their schooling, "... it is vital that we start with algorithmic thinking early on, and help the students advance towards, ultimately, mastery of the subject" (Hromkovic et al. 2017).

With this mandate for all students to learn algorithmic thinking skills, the following examples make use of both digital technologies and more traditional, off-line resources. This reflects the interpretation of algorithmic thinking as a thinking skill, not only a computer or online skill.

Algorithmic Thinking in the Early Years

In the early years, students are supported to understand sequenced events, patterns, and designing solutions. At this level, this might include drawing, discussing, and/or shared writing, rather than formal, written responses. An example is a group of 5-year-old children who are planning for a school excursion. The teacher explains that they will need to pack a picnic for the class to enjoy. As a class, the students make a list of possible foods and drinks they might like to include.

From here, the teacher points out that there is a wide variety of possible sandwich fillings and asks how can we determine all the options so we know what we need to buy? In small groups, students draw ways to represent all the possible sandwich filling combinations and are then led to identify patterns between the groups' drawings. There are a few ingredients that appear to be consistent across the groups: bread, butter, and Vegemite. Each group is asked to redesign their drawing to make this pattern clear. Some draw a giant loaf of bread, others add the word "bread" to each of the

sandwich options they chose. The teacher comments that by looking for patterns they have made useful additions to their drawings. You cannot make a sandwich without bread, but we may not have realized this, if we had not searched for patterns in our data.

The teacher next asks the students to consider how they might best create one drawing or diagram to represent all the options in the class. Again, in small groups, students are supported to design a flow chart that leads students through the sandwich filling options. The flow charts are then combined into a single class flow chart, again highlighting patterns that have emerged, and this is followed by a discussion of the processes and problems they worked through to create the final flow chart.

The teacher highlights the use of patterns to simplify the initial drawings and the role of abstraction in ensuring that they all focused on sandwiches, rather than just on fillings. While the language of algorithmic thinking is likely beyond student's comprehension at this stage, they have begun to develop concepts of patterning and algorithms as tools for problem-solving.

Algorithmic Thinking in the Middle Years

As students approach the middle years of primary schooling, they begin to engage with algorithmic thinking across a wider range of curriculum areas. This might be in an interdisciplinary project or through one specific learning area. This example engages students in geography learning (human land use) and algorithmic thinking strategies.

A class of 10-year-old students is seeking to understand why some areas of the playground are busier than others, as the footy game played at lunchtimes appears to be impacting on those who wish to engage in quiet play activities.

To begin, students have explored the geology of their school grounds and have collected a range of measurements. These include the height above sea level of five locations in the school grounds, the number of students in these five locations at recess times, and the types of play that occur in

each location. The teacher sees an opportunity to engage students in complex problem-solving using algorithmic thinking strategies, namely pattern recognition and decomposition.

The teacher guides students to begin categorizing their data. Students create categories of quiet play, sports games, and noisy, running games. Each student group adds their data to these categories and the teacher leads a discussion about the patterns they identify. She leads the students to make broader, abstracted comments on each category, such as more “people play noisy running games at location three.” She then asks them to assign the locations and height above sea level to each activity in the three categories.

As students complete this task using a Digital Media Board, they begin to reorganize and rename their findings to better fit the categories. Some students make comments about the relationship between height above sea level and the types of play that students undertake.

The teacher uses this comment to introduce ideas of decomposition. They break the data into parts and focus on the data from one location, for one activity. They realize that this data was gathered on a slight hill and is the highest point in the school grounds. The activities at the location are reported as mainly “quiet play.”

Students use this example to generate the hypothesis that higher locations in the school grounds are better for quiet play. The groups then return to their data to validate their findings. They use the Digital Media Board to share their ideas and findings with the class and to generate a whole-class conclusion.

Their findings suggest that if sports play was limited to two main locations in the school grounds, there would be more space for noisy, running games, that would, in turn, and using systems thinking, increase the space for quiet play.

Students are led to discuss the use of pattern recognition and decomposition in understanding the complexity of the problem. Initially, students believed the footy game impacted on the quiet play areas, but their findings suggest that it was

in fact the noisy, running games that were impacted by the footy players, who in turn impacted on the quiet play areas.

Algorithmic Thinking in the Senior Years

In the final years of primary schooling, students are supported to engage with technologies, computer coding, and solution design. In this example, a group of 12-year-old students are engaged in a STEM learning project focused on the exploration of Mars.

The teacher begins by providing a scenario whereby it is some time in the future and Earth’s resources are running low, we are broadly overpopulated, and climate change is regularly resulting in catastrophic disasters. As one way of dealing with these issues, the global community has sent humans to Mars in the hope of colonizing the planet and making human habitation possible.

As the students and the teachers begin to work through this scenario, they move through each of the STEM disciplines. In the area of science, they must consider general requirements for the sustenance of life. Thus, how will food, water, shelter, and breathable air be provided. Quite quickly they may realize that they will need to grow plants. Not only will they provide a source of food but through photosynthesis oxygen will also be released.

Students will design the base station for the Mars settlement. This will draw on digital technologies, engineering, and mathematics. They will plan for how the inhabitants of the base station will move from location to location around the settlement. Imagining that a codable robot (for example, Sphero or Dash bot) is a Mars rover controlled remotely from the base station. This will be achieved by using grid references (or Cartesian coordinates for more advanced learners) and drag and drop coding. The input device for the code would usually be a Bluetooth enabled android or iOS tablet or smartphone. It is suggested that a large-scale map of Mars is created on the floor of the classroom. A number of landmarks or significant areas of interest are included

on the map (for example Olympus Mons, the largest volcano in our solar system and Valles Marineris, a valley larger than the Grand Canyon on Earth). Students should draw on their developing understanding of abstraction, systems thinking, pattern recognition, and decomposition to plan and have the rover navigate its way around a preplanned circuit.

We suggest the teacher identify the component parts of algorithmic thinking and create formative assessment matrices to provide feedback to students about their progress and areas for future growth.

Summary

Algorithmic thinking can be seen as encompassing a range of skills including the four areas of design thinking, decomposition, pattern recognition, and abstraction. In this entry, we have described and explored several activities that can help students to develop algorithmic thinking in the early, middle, and senior primary school levels.

In the early years, through planning a picnic, students could develop an understanding of basic algorithms represented through drawings. In the middle years, students might generate, record, and analyze data related to playground usage. The context of Mars exploration, in the upper primary years, connects students' learning to ongoing media reports and represents an interdisciplinary and engaging approach to algorithmic thinking within STEM learning.

This entry presents algorithmic thinking as an essential and strategic focus area for primary school learning as we continue to see the demand for these technological skills increase in the workplace.

Cross-References

- [Computational Thinking](#)
- [Informatics](#)

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Anatomy Learning

- [Indications for Kinesthetic Learning Through Haptic Devices](#)

Android

- [Applying Software Engineering Principles in Android Development](#)

Android Apps-Based Learning Approach

- [Android-Based Mobile Apps for Hands-On Education](#)

Android-Based Mobile Apps for Hands-On Education

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Synonyms

Android apps-based learning approach; Firewall; Information security education; Security hands-on labs

Introduction

As mobile devices grow increasingly in popularity within the student community, novel educational activities and tools, as well as learning approaches, can be developed to get benefit from this prevalence of mobile devices (e.g., mobility and closeness to students' daily lives). Particularly, information security education should reflect the current trend in computing platforms away from the desktop and toward mobile devices.

Nowadays, the need to use a practice- and application-oriented approach in information security education is paramount (Chen and Lin 2007). Hands-on learning through lab exercises plays a key role in information security education. In fact, a security education curriculum that does not give the students the opportunity to experiment in practice with security techniques cannot prepare them to be able to protect efficiently the confidentiality, integrity, and availability of computer systems and assets. In addition, rather than only teaching abstract concepts and assigning abstract exercises, courses that also engage students in real-world settings will promote effective information security education (EDUCAUSE 2014; Loveland 2011).

Hands-on lab exercises on various information security topics have focus primarily on desktop environments, whether physical or virtual, and consequently can be implemented only inside

isolated laboratories environments (Whitman et al. 2014; Trabelsi et al. 2013; Trabelsi and Alketbi 2013; Trabelsi 2011; Vigna 2003a, b; Yuan and Zhong 2008; Caltagirone et al. 2006; Hill et al. 2001; and Trabelsi and Mustafa 2014). Recently, the computing landscape, however, is shifting. The dominant computing platform is becoming the mobile device (Andrus and Nieh 2012). Nevertheless, the real-world constraints and operating environment of mobile devices are quite different from traditional desktop-based laboratory environment. Therefore, it is important for students to learn in this new environment whose prevalence and popularity can be used to create new hands-on lab exercises and tools for information security education (Andrus and Nieh 2012).

In fact, over the last decade, the use of mobile devices for both personal and business purposes has exploded. The arrival of smart mobile devices (Google-Android-based smartphones and tablets) and the booming of mobile applications (known as apps) in recent years have only accelerated this trend (Bhattacharya et al. 2014). Mobile devices have been consequently turned into powerful general-purpose computing platforms. More and more users and businesses use mobile devices for processing personal, financial, and commercial data or use them to organize their work and private life. Particularly, in the academia environment, more and more students are using mobile devices for both personal and academic reasons (Levine and Kossuth 2011). Hence, an enormous array of mobile devices is making its way to college campuses. As smart mobile devices grow increasingly in popularity within the student community, novel educational activities and tools, as well as learning approaches, can be developed to get benefit from this prevalence of mobile devices (e.g., mobility and closeness to students' daily lives). Hence, the teaching of information security concepts should reflect the current trend in computing platforms away from the desktop and toward mobile devices.

As the need to use a hands-on-based learning approach in information security education is paramount, and as mobile platforms grow increasingly in popularity within the students' community, learning approaches that aim at taking

advantages of the benefits of mobile devices and the best practices in learning information security should be explored. The approaches should aim to promote students' interests and increase their self-efficacy. In this work, a learning approach that offers two Android apps for the students to further learn the intricacies of network traffic filtering and enhance their hands-on skills on firewall filtering rules implementation is presented. The apps allows students to further practice network traffic filtering outside the traditional isolated laboratory environment, in the real-world environment, i.e., anywhere and anytime, at the students' convenience. The two Android apps are a firewall app and a network packet generator app, called Advanced Firewall and Packet Generator, respectively. Based on statistics from Google Play Store, in September 2019, the Packet Generator app has been rated 4.0 with over 500,000 downloads worldwide. As a consequence, in addition to the traditional inside laboratory activities which are limited by the time allocated and often do not reflect the real-world settings, students will be able to continue practicing further network packet filtering using their mobile devices in the real-world environment, at their convenience. The impact of the two Android apps on the students' performance in terms of achieving the course outcomes is also discussed.

Efficient Learning Approach

The importance of hands-on learning has long been recognized in the learning theory literature (Du et al. 2010). In traditional information security programs, students are expected to be heavily involved in hands-on lab activities. Therefore, the first characteristic of an efficient learning approach is its hands-on-based learning that couples security policies analysis with protection solution practices. In practice, this consists into implementing and testing the appropriate firewall filtering rules for specific security policies, on Android mobile devices.

The second characteristic of an efficient learning approach is its real-world relevant learning. The mobile device itself is becoming more

relevant than other existing learning platforms to real-world applications. As a consequence and in addition to the inside laboratory activities, students are encouraged to test and debug firewall filtering rules in the real-world environment, using mobile devices.

Thirdly, Android platform has been chosen over iOS platform to develop the proposed educational apps for several reasons. First, Android is the fastest-growing mobile platform (Andrus and Nieh 2012; Guo et al. 2013) to date, and its popularity makes it of tremendous interest to students. Second, Android platform is open-sourced, while Apple iOS platform has license restrictions. Moreover, since Android is based on the open-source Linux kernel, students can leverage a wealth of Linux tools and documentation. That is, Android allows exploration of a complete production system including the OS kernel, user space libraries, and a graphical user environment written in Java. Third, as a commercial platform, Android continues to be developed and improved which naturally evolves the platform as a pedagogical tool, enabling students to learn in a modern context.

Hands-on Learning Activities on Firewalls

A pedagogical model to teach firewalls concepts consists usually of two main phases. In the first phase, and during the hands-on lab activities, the instructor asks the students to discuss and analyze a set of security policies related to a variety of network traffic scenarios. Then, the instructor asks students to write the appropriate filtering rules for each security policy. Students are then instructed to implement and test filtering rules using classical firewall devices and wired or wireless local area networks.

In the second phase, students are then instructed on how to implement and test their firewall filtering rules on their mobile devices, using step-by-step tutorials. In fact, in addition to the inside laboratory activities, students are requested to test and debug firewall filtering rules in the real-world environment, using mobile

devices. This will help students to obtain an instant gratification and confidence from the hands-on practice and encourage them to create specific filtering rules to filter real-world network traffic. This also has the additional benefits of not only facilitating students to learn network traffic filtering skills but also heightening their awareness and understanding of firewall concepts in the real-world environment.

Design Considerations

Firewalls control the access into and from networks and computers based on a set of filtering rules, which reflect and enforce the organization's security policy. It is the firewall's job to make filtering decision on every packet that crosses it: either to let it pass or to drop it.

Firewall and network packet filtering is considered an important topic for a course on network security. There are basic network packet filtering topics that should be taught when offering a security course on firewalls, namely, basic network packet filtering, common standard services filtering, and nonstandard services filtering. There are also advanced network packet filtering topics, such as stateful firewall packet filtering using TCP flags, and packet deep inspection (DPI), also known as packet content inspection, and consistency verification of the filtering rules.

Ideally, when designing and implementing an educational firewall application, the above basic and advanced topics should be taken into consideration to help students improving their hands-on security skills on firewall configuration and network packet filtering. In addition, the educational firewall application should offer a user-friendly GUI interface to allow students easily create and manipulate filtering rules, including updating the values of the filtering rule's fields and the order of the filtering rules. Students should also use means to test and debug the implemented filtering rules and should be immersed in a real-world relevant learning environment, by taking advantage of the benefits of mobile devices.



Android-Based Mobile Apps for Hands-On Education, Fig. 1 Apps of the Android learning approach

Android Apps

The discussed learning approach uses the two Android-based apps: Advanced Firewall and Packet Generator apps (Fig. 1). Advanced Firewall app allows implementing filtering rules and/or selecting rules from a set of predefined rules to filter a diversity of network traffic types and Internet services. Packet Generator app is used to generate specific network traffic to test the efficiency of the implemented filtering rules relative to the outgoing and incoming network traffic. The use of both apps allows students to practice implementation, testing, and debugging of firewall filtering rules, while they are outside the isolated laboratory environment. Hence, in addition to the inside laboratory activities, students will get further chances to improve their hands-on security skills on firewall concepts, using their Android mobile devices. The following subsections describe the two apps.

Advanced Firewall App

Advanced Firewall app offers a set of basic firewall functions that allow performing the following:

- Implement basic filtering rules to filter TCP and UDP network traffic. The filtering rules are defined by setting the values of the source/destination IP addresses and the source/destination ports.
- Implement basic filtering rules to filter ICMP network traffic. The filtering rules are defined by setting the values of the source/destination IP addresses and the ICMP Type/Code fields.

- Select rules from a list of predefined rules to filter standard Internet services, such as Web, Email (SMTP/POP3), and FTP.
- Implement filtering rules to filter nonstandard TCP and UDP services.
- View the logs data of filtered network packets.

A future version of Advanced Firewall app can be enhanced to include more educational firewall functions to cover advanced topics, such as stateful firewall packet filtering using TCP flags, application gateway firewalls (Proxy), and Virtual Private Networks (VPN). The following subsections describe in details the current main basic security functions of Advanced Firewall app.

Basic Packet Filtering

Basic firewall packet filtering is the selective passing or blocking of packets as they pass through a network interface. The most often used criteria that packet filtering use when inspecting packets are source and destination IP addresses, source and destination TCP/UDP ports, and type and code fields in an ICMP header (Northcutt et al. 2005). Firewall users need to have basic knowledge about TCP/IP protocols and Internet services in order to be able to create the appropriate rules for filtering specific network traffic.

Predefined Filtering Rules for Standard Internet Services

Standard Internet services run usually on standard ports. Standard ports range is in the interval of 1 to

1023. For example, the standard ports for Web (HTTP) and FTP services are 80 and 21, respectively. Firewalls include usually predefined rules to filter standard services. Firewall users can select rules from the list of offered predefined rules to filter network traffic relative to Internet services. However, in contrast to writing basic filtering rules, firewall users need simply to have general knowledge about Internet services, to be able to select the appropriate predefined filtering rule for each specific Internet service.

Nonstandard Services Filtering

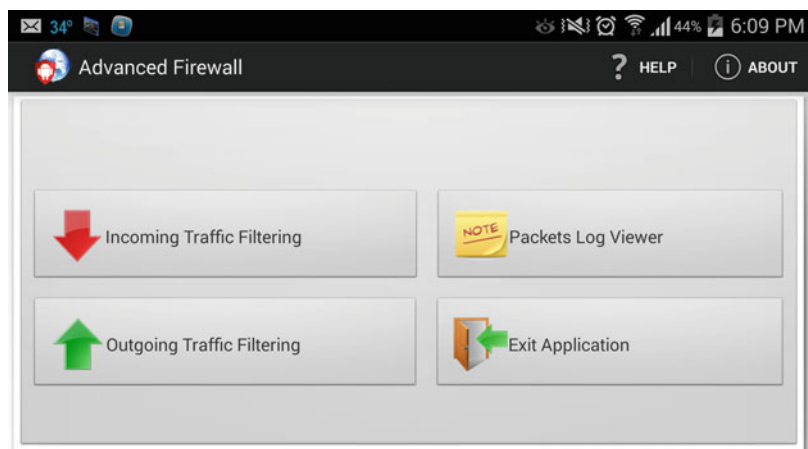
Nonstandard services run on nonstandard ports. Nonstandard port numbers are usually larger than 1023. Firewalls are unable to filter nonstandard services unless the user provides the firewall with the TCP or UDP ports of the nonstandard services to be filtered. In practice, this is achieved by creating a new service profile for the nonstandard service, and by specifying its corresponding TCP or UDP port number.

App's Implementation

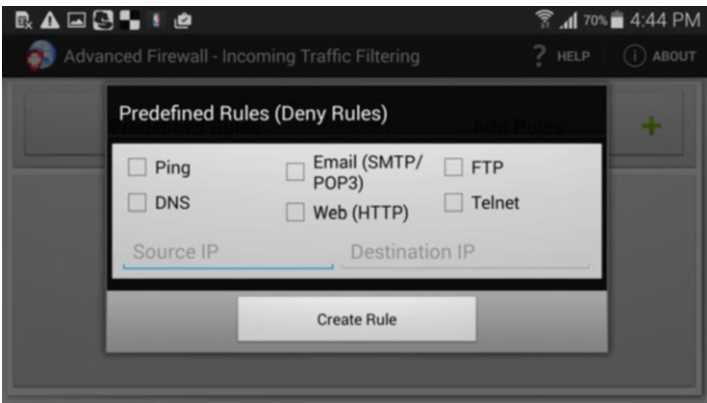
Advanced Firewall app is written in Java language using Eclipse IDE. The main GUI interface of Advanced Firewall app allows the mobile device's users to select the source of the network traffic (incoming or outgoing) to be filtered or to view the log data relative to the previously filtered packets, as shown in Fig. 2.

To filter network traffic, the user can either select filtering rules, from a set of predefined

Android-Based Mobile Apps for Hands-On Education, Fig. 2 Main user interface of Advanced Firewall app



Android-Based Mobile Apps for Hands-On Education, Fig. 3 List of predefined filtering rules offered by Advanced Firewall app



Android-Based Mobile Apps for Hands-On Education, Fig. 4 List of selected and user-created filtering rules



filtering rules, or create new filtering rules. Figure 3 shows the list of predefined rules offered by Advanced Firewall app for filtering Ping traffic and Web/FTP/DNS/Email/Telnet services.

As an example, Fig. 4 shows a list of selected predefined and user-created filtering rules.

Packet Generator App

The discussed learning platform also uses a network packet generator app, named Packet Generator, for generating specific network traffic to test the efficiency and correctness of the implemented filtering rules in mobile devices. In fact, the objective behind developing this app is to allow a single student to conduct, from a mobile device, self-testing of his implemented filtering rules for the outgoing network traffic. However, to test the filtering rules for the incoming network traffic, Packet Generator app should be installed into another mobile

device from which the network test traffic can be generated. Packet Generator app can be used also to test the resilience of target hosts against denial of service (DoS) attacks traffic (Trabelsi et al. 2013), by generating network flood traffic at a high rate.

Implementation of the App

Packet Generator app is written in Java language using Eclipse IDE. The application is freely downloadable from Google Play Store (<https://play.google.com/>). Based on statistics from the Google Play Store, and as per September 2019, Packet Generator app turned popular with over 500,000 downloads worldwide and a 4.00 users' rating.

Using a friendly GUI interface, the app allows Android mobile device's users to specify the type of the network traffic to be generated (i.e., TCP, UDP, or ICMP). Practically, for TCP and UDP

network traffic, the app offers the user the options to specify the IP address of a target host and a random or specific TCP or UDP port number. For ICMP network traffic, the app offers the user the options to specify the IP address of a target host and the ICMP Type and Code field values.

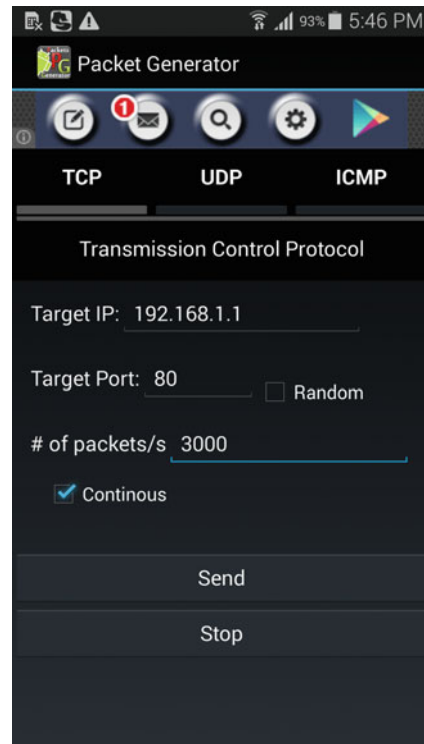
For any network traffic type, the user can choose the rate of traffic to be generated (i.e., number of packets per second) and whether or not the desired traffic will be sent continuously. In addition, for ICMP traffic, the user can select to flood the target host. In this case, the flooding traffic is sent at the highest possible rate that the mobile device can support. In general, flooding option in Packet Generator app allows testing the resilience of target hosts against DoS attack traffic.

DoS Attacks Generation Using Packet Generator App

DoS attacks topic is considered as one of the major topics for courses on network security, especially for courses that are concerned with intrusion and malicious network activities detection and prevention. Commonly, a DoS attack attempts to render a system unusable or significantly slows down the system for legitimate users by overloading the resources so no one else can access it. A DoS attack may target a user, to prevent him from making outgoing connections on the network. A DoS attack may also target an entire organization, to either prevent outgoing traffic or to prevent incoming traffic to certain network services, such as the organization web page.

DoS attacks are much easier to accomplish than remotely gaining administrative access to a target system. Because of this, DoS attacks have become very common on the Internet. Most DoS attacks rely upon weaknesses in the TCP/IP protocols. For example, a SYN flood DoS attack occurs when a host becomes so overwhelmed by SYN packets initiating incomplete connection requests that it can no longer process legitimate connection requests.

In information security education, hands-on lab exercises on DoS attacks allow usually



Android-Based Mobile Apps for Hands-On Education, Fig. 5 TCP packets generation example

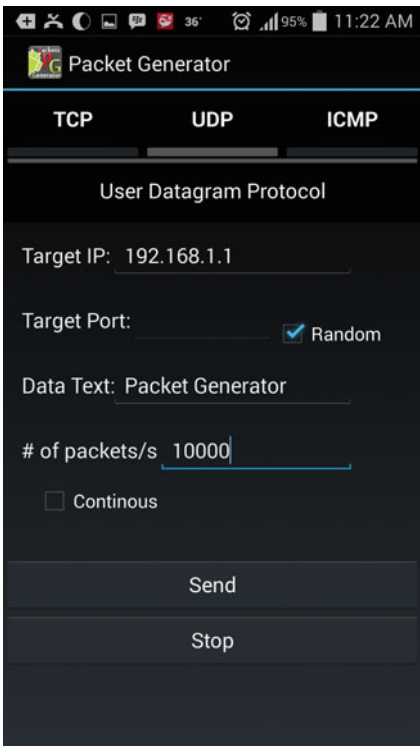
students to learn DoS attack traffic generation and implement the corresponding defensive solutions. Practically, students can use network packet generator tools to generate DoS attack traffic. However, it is not recommended to use DoS tools developed by hackers or untrusted sources, since the tools may carry virus and malicious codes.

The following screenshots are examples on how to use Packet Generator app to generate a diversity of common DoS attacks.

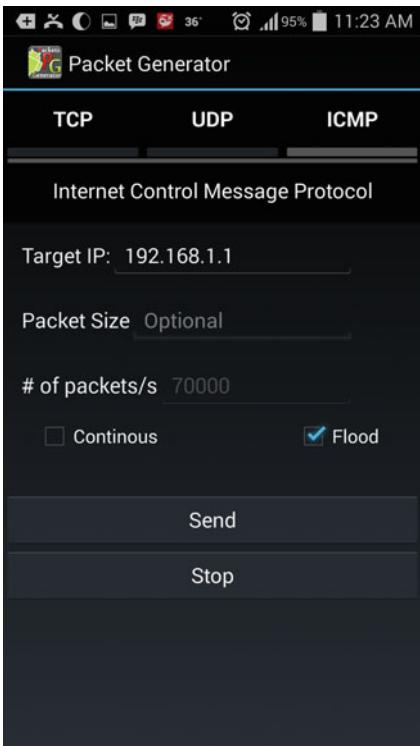
Figure 5 shows how to generate continuously TCP packets targeting port 80 in a host with IP address 192.168.1.1, at the rate of 3000 packets per second.

Figure 6 shows how to generate 1000 UDP packets in 1 s, targeting random ports in a host with IP address 192.168.1.1.

Figure 7 shows how to flood a target host with IP address 192.168.1.1 with ICMP packets, using the highest traffic rate that the mobile device can generate.



Android-Based Mobile Apps for Hands-On Education, Fig. 6 UDP packets generation example



Android-Based Mobile Apps for Hands-On Education, Fig. 7 ICMP flooding traffic generation

Related Android Firewall Apps

The development of Android firewall apps is not a new idea by itself as there are many Android apps acting as firewalls. In Google Play Store, many Android firewall apps have been identified, namely, *DroidWall*, *Android firewall*, *Root firewall*, *Mobiwol firewall*, *Firewall builder*, *Honeybadger firewall*, *Traffic firewall*, *Firewall plus*, *IP spoofing detector and firewall*, *NoRoot Firewall*, *AFWall+*, *Firewall Gold*, and *LostNet NoRoot Firewall*. Table 1 summarizes the firewall features of these Android apps, particularly their abilities to allow users to easily and freely implement and manipulate firewall filtering rules, as well as their limitations and strengths. In addition, Table 1 compares these apps with the proposed Advanced Firewall app.

The analysis results of these apps conclude that they have been designed almost without educational objectives and offer limited firewall functions to create and manipulate filtering rules.

Moreover, the use of some apps is complex and often requires advanced knowledge of networking concepts and protocols. For example, *Android firewall* and *Firewall builder* allow the user to enter his/her custom filtering rules in script syntax. Also, the GUI interfaces of some apps do not allow friendly view of the implemented filtering rules. There are many apps that do not allow viewing the log data of the filtered network packets, such as *DroidWall*, *Android firewall*, *Root firewall*, *Firewall builder*, *Traffic firewall*, *Firewall plus*, *IP spoofing detector and firewall*, *Firewall Gold*, and *LostNet NoRoot Firewall*.

Other apps do not allow free manipulation of the fields of the filtering rules. For example, in the case of filtering TCP and UDP packets, many apps do not allow setting the source and destination IP addresses and/or the source and destination ports (*DroidWall*, *Android firewall*, *Root firewall*, *Mobiwol firewall*, *Traffic firewall*, *Firewall plus*, *IP spoofing detector and firewall*, *AFWall+*, *Firewall Gold*, *LostNet NoRoot Firewall*). In case of

Android-Based Mobile Apps for Hands-On Education, Table 1 Related Android firewall apps’ features

Firewall features	Apps supporting this feature	Advanced Firewall (Our Firewall App)
Offer easy-to-use GUI interface	[DroidWall, Android firewall, Root firewall, Mobiwal firewall, Honeybadger firewall, Traffic firewall, Firewall plus, IP spoofing detector, NoRoot firewall, AFWall+, Firewall Gold, LostNet NoRoot firewall]	✓
Filter TCP and UDP traffic based on IP address	[Firewall builder, Honeybadger Firewall, NoRoot firewall]	✓
Filter TCP and UDP traffic based on port number	[Firewall builder, NoRoot firewall]	✓
View log data of dropped packets	[Mobiwal firewall, Honeybadger firewall, NoRoot firewall, AFWall+]	✓
Filter ICMP traffic based on the Type and Code fields’ values	None	✓
Allow selecting predefined filtering rules for specific services and applications	[Firewall builder]	✓
Filter Web traffic based on URL address	[Honeybadger firewall, IP spoofing detector]	✓
Filter nonstandard services	[DroidWall, Android firewall, Root firewall, Mobiwal firewall, Honeybadger firewall, Traffic firewall, Firewall plus]	✓
Filter both incoming and outgoing traffic	[Firewall builder, Honeybadger firewall, NoRoot firewall]	✓

filtering ICMP traffic, all investigated Android firewall apps do not allow to set the ICMP Type and Code fields.

On the other hand, most investigated apps focus on controlling solely the other apps installed in the mobile device that require accessing Internet. That is, the users can solely allow or deny the installed apps to access the Internet. *DroidWall*, *Root Firewall*, and *Mobiwal* apps are examples of such apps.

In contrast, Advanced Firewall app has been designed mainly for educational purpose and offers a more user-friendly GUI interface to implement and manipulate firewall filtering rules. Furthermore, Advanced Firewall app offers a more comprehensive set of educational firewall functions that are appropriate and useful for information security education. Hence, compared to the investigated aforementioned Android firewall apps, Advanced Firewall app is more adequate for implementing educational hands-on lab exercises on firewall packet filtering, allows students to better anatomize firewall

concepts in real-world environment and outside laboratory activities, and consequently enhances further student’s firewall hands-on skills.

Assessment Process

Course learning outcomes achievement is assessed using a comprehensive assessment and evaluation system (Ibrahim et al. 2015). The assessment system consists of three main processes based on ABET guidelines (Sanderson 2009). At the lower level, the course assessment process is used to measure the achievement of course outcomes (COs). COs describe the knowledge, skills, and/or competencies that the students should have or be able to demonstrate upon completion of the course. COs assessment results are then combined with other program-level assessment tools (e.g., student survey, exit exams, exit interview, etc.) to measure the achievement of the student outcomes (SOs) at the next stage. SOs describe what students are expected to learn and

be able to do by the time of their graduation, which include cognitive, affective, behavioral, social, and ethical performances. At the third level, the program educational objectives (PEOs) are measured and evaluated. PEOs are broad statements that describe the strategic career and long-term professional accomplishments the program is preparing its graduates to achieve 3–5 years after graduation.

During the course offering, each instructor teaching the course is responsible for collating the assessment data for the taught section(s) and preparing a simplified section assessment report. The section assessment reports are then sent to the course coordinator. To minimize the assessment effort, the section assessment report includes only the following information:

1. The number of students
2. The assessment tools used
3. The mean and standard deviation for each outcome achievement level
4. Any assessment-related remark (optional)

Although bimodal distribution could be more appropriate in some situations to model the students' performance, the tool assumed a Normal distribution for the students' performance to facilitate the aggregation of the assessment data from different sections and different assessment instruments producing the overall CO assessment results. To calculate the mean and the standard deviation for each learning outcome, the course coordinator aggregates the performance of the students in each used assessment tool. Each course c has a set of outcomes O_c , a set of assessment tools T_c , and is offered to a set of sections S_c . Therefore, the mean and standard deviation for outcome o is calculated as follows:

$$\mu_{soc} = \frac{\sum_{t \in T_c} \mu_{tsoc} \times \alpha_{to}}{\sum_{t \in T_c} \alpha_{to}} \quad (1)$$

$$\sigma_{soc} = \sqrt{\frac{\sum_{t \in T_c} \sigma_{tsoc}^2 \times \alpha_{to}}{\sum_{t \in T_c} \alpha_{to}}} \quad (2)$$

where μ_{tsoc} and σ_{tsoc} are the mean and standard deviation when tool " t " is used in section " s " to assess outcome " o " of course " c ," α_{to} is a mapping factor that determines the contribution of the assessment tool t to the achievement of outcome o such that $\sum_{o \in O_c} \alpha_{to} \leq 1$.

The course coordinator compiles the received section assessment reports and calculates the aggregated course-level assessment results. Using the mean and standard deviation for measuring the achievement of the outcomes at the section level facilitates the aggregation of the results from different sections to calculate the overall course assessment, regardless of the assessment tool used in each section. For each outcome o of course c , the aggregated mean and standard deviation are calculated as follows:

$$\mu_{oc} = \frac{\sum_{s \in S_c} \mu_{soc} \times n_s}{\sum_{s \in S_c} n_s}, \quad (3)$$

$$\sigma_{oc} = \sqrt{\frac{\sum_{s \in S_c} \sigma_{soc}^2 \times n_s}{\sum_{s \in S_c} n_s}}, \quad (4)$$

where n_s is the number of students in section s . Assuming Normal distribution, the achievement level of outcome o of course c (noted A_{co} below) is calculated as the percentage of students who scored above a predefined cutoff threshold λ , as shown next:

$$A_{oc} = 0.5 - 0.5 \times \text{erf}\left(\frac{\lambda - \mu_{oc}}{\sigma_{oc} \times \sqrt{2}}\right). \quad (5)$$

For example, assume that $\mu_{co} = 0.74$, $\sigma_{co} = 0.093$, and $\lambda = 0.7$, the outcome achievement level in this case is the percentage of students whose score is above λ , which in this case is 66.64%.

Course Learning Outcomes Assessment

As a case study, the two discussed Android apps have been offered to students enrolled in a course called Network Border Control (SECB358)

Android-Based Mobile Apps for Hands-On Education, Table 2 Mapping the course outcomes to Bloom's taxonomy

Outcome	Level of Bloom's taxonomy
CO1: Describe TCP/IP protocols and network services	Analysis
CO2: Identify common security threats	Analysis
CO3: Configure personal firewalls, network firewalls, and VPNs	Synthesis
CO4: Implement firewall filtering rules for different network architectures and services	Synthesis
CO 5: Evaluate different types of network architectures	Evaluation

during several academic years. SECB358 is a course that is concerned mainly with network packet filtering, firewall, and VPN topics. A major topic taught in SECB358 course is firewall filtering rules implementation. The course also offers students an extensive set of hands-on lab exercises on these topics. SECB358 course has five learning outcomes, as shown in Table 2. Since SECB358 is an advanced course in information security, the outcomes have been selected carefully to reflect the top three levels in Bloom's taxonomy of cognitive domain (analysis, synthesis, and evaluation).

During the 2009/2010, 2010/2011, and 2011/2012 academic years, students enrolled in SECB358 course were not offered the two Android apps. Students had the opportunity to practice firewall packet filtering, only in the in-campus isolated labs environment. In addition, students are allowed to practice only for a limited time. However, starting from fall 2012, SECB358 course's committee decided to offer the two Android apps to allow students to further practice firewall packet filtering implementation outside the isolated lab environment.

Among the five COs (Table 2), the Android apps have impact only on the course outcome CO4, since the apps are concerned with the implementation and testing of firewall filtering rules. To compare the achievement of the course outcome CO4 before and after the introduction of the Android apps, four assessment tools that are

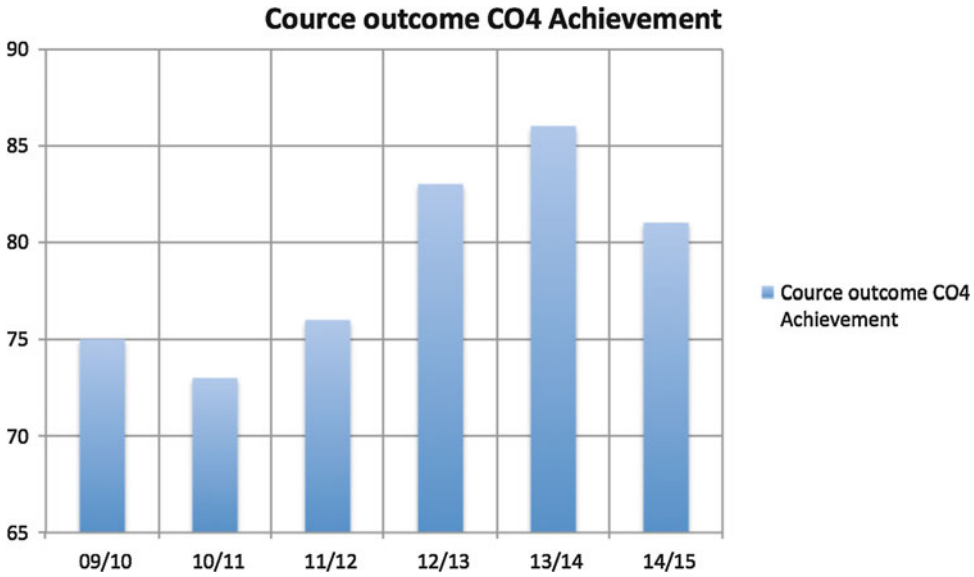
related to firewall filtering rule implementation topic have been selected, namely, two quizzes, three lab exercises, two midterm questions, and two final exam questions. The grades of the students in these quizzes, lab exercises, and questions are measured, normalized, and then aggregated using (Eqs. 1 and 2) to calculate the achievement level of the course outcome CO4.

Figure 8 illustrates the achievement of the course outcome (CO4) for six consecutive academic years, from 2009/2010 to 2014/2015. It shows an important improvement in the achievement level of the course outcome CO4 after introducing several new hands-on lab exercises on firewall filtering rules and the two discussed Android apps in fall 2012. The assessment results show that the achievement level of CO4 in fall 2012 improved by about 7%, compared to the achievement level in the previous academic year (2011–2012).

In addition, Table 3 compares the CO4 achievement level of the 2011/2012 and the 2013/2014 academic years in detail. It shows that the 9% improvement in the achievement level of CO4, from 77% to 86%, can be interpreted as 11.9% and 5.9% increase in the number of students scored above 90% and 80%, respectively, and 10.8% and 6.4% drop in the number of students scored below 60% and 70%, respectively.

The aforementioned assessment results clearly show that starting from fall 2012, the achievement level of the course outcome CO4 (which is concerned mainly with the students' hands-on skills on firewall filtering rules implementation) has improved compared to the previous academic year. In principal, this is apparently due to the fact that the introduction of several new hands-on lab exercises on firewalls and the proposed Android apps allowed students to improve considerably their hands-on skills on firewall filtering rules implementation and better anatomized this topic. The students have learned better with the offered Android apps, which had a positive effect on their performance.

However, to show that the introduction of the apps contributed to affect those assessment results, mainly the learning outcome CO4's



Android-Based Mobile Apps for Hands-On Education, Fig. 8 Course outcome CO4 achievement

Android-Based Mobile Apps for Hands-On Education, Table 3 Detailed description of the course outcome CO4 achievement

	CO-4	
	2010/2011 (%)	2013/2014 (%)
CO < 60%	20.0	9.2
60% ≤ CO < 70%	17.8	11.4
70% ≤ CO < 80%	21.9	21.3
80% ≤ CO < 90%	19.6	25.5
90% ≤ CO	20.7	32.6

achievement level, anonymous student questionnaires were administrated to identify the level of impact of the proposed apps on the students' hands-on skills on firewalls. Overall, the questionnaire results supported the fact that the discussed learning platform had a positive impact on improving the students' hands-on security skills on firewalls and consequently contributed to enhancing the achievement of the learning outcome CO4.

Discussion

The following discussion is based on the data collected from 2 anonymous questionnaires

administered to 120 students, who were enrolled in SECB358 course and who over 3 academic years (2012/2013, 2013/2014, and 2014/2015) used the 2 Android apps. The first questionnaire's objective was to measure the students' satisfaction level and collect their feedbacks. The second questionnaire's objective was to identify the locations where the apps have been used and the students' motivations behind using the apps.

In the first anonymous questionnaire, the majority of the students provided positive feedbacks and enjoyed the Android security practices. In fact, most of the students strongly agreed or agreed that Advanced Firewall app contributed significantly to the closeness of firewall technologies to their daily lives and promoted their interests on firewalls (Table 4, Q. 1 and Q. 2).

The results of the questionnaire showed that about 86% of the students who answered the questionnaire felt that Advanced Firewall app to be useful and helped them better understand the theoretical firewall concepts taught in the lecture (Table 4, Q. 3). The questionnaire also revealed that about 85% of the students strongly agreed or agreed that the proposed apps helped them to develop further their hands-on skills (Table 4, Q. 6), and about 91% of the students strongly

Android-Based Mobile Apps for Hands-On Education, Table 4 Student feedback questionnaire results

Question	Response
Q. 1. Do you think that Advanced Firewall app contributed to the closeness of firewall technologies to your daily lives?	2% Strongly disagree 1% Disagree 5% Neutral 8% Agree 85% Strongly agree
Q. 2. Do you think that Advanced Firewall app promoted your interests on firewalls?	0% Strongly disagree 1% Disagree 3% Neutral 5% Agree 91% Strongly agree
Q. 3. Do you feel that Advanced Firewall app is useful and helped you better understand the theoretical firewall concepts taught in the lecture?	4% Disagree 10% Neutral 1% Agree 85% Strongly agree
Q. 4. Do you think Advanced Firewall app offers to you the necessary basic firewall functions learned in the lecture?	3% Disagree 8% Neutral 10% Agree 77% Strongly agree
Q. 5. Do you think Advanced Firewall app offers to you the necessary advanced firewall functions learned in the lecture?	95% Disagree 3% Neutral 2% Agree 1% Strongly agree
Q. 6. Do you feel that Advanced Firewall app helped you to develop further your hands-on skills on firewall filtering rules implementation?	7% Disagree 8% Neutral 13% Agree 72% Strongly agree
Q. 7. How likely are you to recommend Advanced Firewall app to others to practice firewall filtering rules implementation outside the laboratory environment, at their convenience?	5% Disagree 6% Neutral 8% Agree 81% Strongly agree
Q. 8. Would you like to see similar Android apps offered to students for other security topics, such as intrusion detection?	5% Disagree 4% Neutral 18% Agree 73% Strongly agree
Q. 9. Do you think that Packet Generator app helped to test the correctness of your filtering rules?	5% Disagree 4% Neutral 18% Agree 73% Strongly agree

agreed or agreed to see similar Android apps offered to students for other security topics, such as intrusion detection systems (Table 4, Q. 8).

Moreover, most students recommended offering Advanced Firewall app to students to practice firewall filtering rules implementation, outside the laboratory environment, at their convenience, after practicing the traditional hands-on exercises inside the laboratory rooms (Table 4, Q. 7).

Also, the questionnaire results showed that 87% of the students strongly agreed or agreed that Advanced Firewall app offered to them all the necessary basic firewall functions learned in the lecture (Table 4, Q. 4). However, 95% of them strongly disagreed that Advanced Firewall app offered to them all the necessary advanced firewall functions, such as DPI and VPN. This is explained by the fact that the version of Advanced Firewall app offered to students lacked advanced firewall functions (Table 4, Q. 5).

Overall, the questionnaire results support the fact that the discussed Android learning platform had a positive impact on the students' hands-on security skills and consequently would contribute to enhancing the achievement of the course learning outcomes. In fact, the two Android apps allowed students to better anatomize and assimilate the firewall concepts learned from the lecture.

Regarding the second questionnaire (Table 5), the results showed that about 98% of the students used the two Android apps outside the laboratory environment at many locations, mainly at the school and homes (Table 5, Q. 1). In addition, 78% of the students used the apps to prepare for the exams and continued using the apps even after the exams to protect their mobile devices or to practice further (Table 5, Q. 2).

The results of the second questionnaire showed that the major objective of providing an Android-based learning approach to allow students to further practice firewall filtering rules implementation, outside the in-campus isolated laboratory environment, in the real-world, anywhere and anytime, and at the students' convenience, is achieved.

Conclusion

This entry discussed a learning activity that uses two Android apps to enhance students' hands-on

Android-Based Mobile Apps for Hands-On Education, Table 5 Students questionnaire results

Question	Response
Q. 1. Outside the laboratory room, where did you use <i>Advanced Firewall and Packet Generator</i> apps to implement and test firewall filtering rules?	2%: I never used them outside the laboratory room 30%: Only at the school 20%: Only at home 48%: At many locations (Schools, home, and others)
Q. 2. Outside the laboratory room, how often did you use <i>Advanced Firewall and Packet Generator</i> apps to implement and test firewall filtering rules?	2%: I never used them outside the laboratory room 20%: I used them few times to prepare for the exams 78%: I used them many times even after the exams to protect my mobile device or to practice further

skills on firewalls concepts. The main objective is to demonstrate how mobile devices can be used to develop novel educational activities and tools and learning approaches that attempt to get benefit from the prevalence of mobile devices within the student community. The data collected using assessment tools and students' feedback questionnaire demonstrates clearly that the discussed Android-based learning activity had a positive impact on the students' firewall hands-on skills and on the students' performance in terms of achieving the course learning outcomes. Moreover, a comparative analysis of various related Android apps with the discussed apps emphasizes their significance, mainly for the academic environment.

The educational case study presented in this entry demonstrates clearly that mobile technology has the potential to transform considerably the learning field by allowing to develop novel educational activities, approaches, and tools that take advantages of the benefits of this technology and its increase growth in popularity within the student community. Therefore, the existing learning approaches, pedagogical models, and educational tools should reflect the current trend in computing platforms away from the desktop and toward mobile technologies.

Moreover, as institutions adopt new mobile technologies, they should look beyond using these devices for teaching and examine how mobile computing can increase engagement and cultivate strong communities of learners. In fact, mobile computing has the potential to transform learning and engages students in learning in different ways. Consequently, as mobile devices have become more common on campuses, many innovative projects have emerged that engage students and change the way faculty teach courses.

Cross-References

- [Mobile Computing and Mobile Learning](#)
- [Mobile Learning and Ubiquitous Learning](#)
- [Mobile Learning, Challenges in](#)
- [WalkAbout Framework for Contextual Learning Through Mobile Serious Games](#)

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- [Human, Social, and Ethical Aspects of Information Technology Management Systems](#)
-

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Applications

- [School Management Software in a Primary School in Victoria, Use of](#)
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Applying Software Engineering Principles in Android Development

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Synonyms

[Android](#); [Java](#); [Mobile application development](#); [Software design](#); [Software design principles](#)

Introduction

The tremendous popularity of mobile computing and Android in particular has attracted millions of developers who see opportunities for building their own start-ups. As a consequence computer science students express an increasing interest

into the related technology of Java development for Android applications. Android projects are complex by nature and relatively large software products, while their development calls for the application of established software engineering practices and tools.

Computer science and information technology curricula include software engineering as a key knowledge area (ACM 2013), and as a result, most computer science-related departments offer at least one “conventional” software engineering course. By conventional we mean that in most cases, the introduced concepts are exemplified on either desktop applications standing individually on a personal computer and recently on web applications employing server and/or client side development. To the best of our knowledge, there are very few courses that introduce software engineering concepts to a mobile software development course. At the same time, software development for particular platforms is often perceived and taught as a purely technological skill with no direct connections to software engineering. The consequence is that even experienced mobile application programmers do not embrace or apply software engineering practices. Moreover, the lure of Android development can serve as a vehicle for conveying software engineering concepts to computer science students in an attractive way. All these issues have resulted in interesting proposals regarding the integration of mobile devices into the computer science curriculum and relevant courses and teaching approaches.

The integration of mobile devices into the computer science curriculum has been discussed in a study by Mahmoud (2008) where the need to consider the important factor of restricted resources (small screen, limited memory, etc.) is stressed. Moreover, the author highlights the difference of compiling an application for a “normal” PC and for a mobile device. It is claimed that introducing mobile devices and the basics of mobile application development as early as possible in introductory programming courses is a necessity. In the context of the described course, the students were asked to develop two versions of a mortgage calculator application: one for a

desktop and one for a mobile platform, so they could distinguish the differences (and similarities) between the two approaches.

A different approach is adopted in the work of Akopian et al. (2013) where the authors rely on already developed templates (Android programs) to teach in a short course, the basic principles of Android development. The students were asked to alter specific aspects in the program by modifying the existing code. The questions and activities have been very carefully structured and explained, in order to guide the student to the correct position of variable or code snippet that needs to be changed. Through structured colored examples, the activities for the students are slowly escalating to the most difficult ones. According to one pre-course and one post-course survey, student’s satisfaction has been achieved along with a strong belief that basic skills have been obtained through the course.

Evidence from evaluations performed by Heckman et al. (2011) implies that teaching lower-level programming courses with more advanced and current technologies such as mobile devices can be beneficial. In particular, the authors taught Java and software engineering courses at the University of Virginia and North Carolina State University utilizing the Android OS platform. Although details about the course are not provided, the goals are similar to the proposed course in this paper, i.e., to teach both Java (such as abstraction) and software engineering concepts (such as design, testing, and patterns) using Android.

Petkovic et al. in 2006 (Petkovic et al. 2006) claimed that practical teaching of software engineering should also focus on teamwork, communication skills, and organizational issues to reflect the globalization and open-source aspects of real software development projects. The authors recommend that students should be divided into small groups of four to six persons in order to simulate real-life software development and undertake the task of constructing a web application through five milestones. The course also emphasizes the need of collaboration without face-to-face meetings, and to this end, the use of version control systems is essential.

The main motivator for their work was that the combination of traditional classroom teaching of processes, teamwork, and communication with a major final project, intensive instructor interaction, and realistic simulation of real software lifecycle is critical. The benefits of cooperative learning where students work together in small groups enhancing each other's learning have been recognized early in the computer science education community (Tenenbergh 1995). The same belief is shared by the authors of the current work and has been taken into account during the design of the proposed course.

The challenges of designing a smartphone software development course based on Android have been discussed by Hu et al. (2010). The paper introduces a full semester course with an emphasis on the underlying platform: the first two parts of the course consist in an introduction to smartphones and their OS. The next three parts are presenting the environment for Android development, while only the seventh part is devoted to software development. The authors are acknowledging three design principles with the second stating that the teaching content should place an emphasis on practice rather than theory and the third mentioning that course contents should meet the needs of the industry.

In this entry, a short course is introduced aiming at illustrating selected software engineering principles, concepts, and techniques in the context of Android application development. The goal is to demonstrate that Java programming for Android applications – which is usually perceived as an isolated activity – can benefit largely from applying software engineering best practices. The course is structured around a base Android application that is gradually enhanced by discussing limitations or opportunities that can be addressed by appropriate techniques or guidelines such as design principles, design patterns, refactorings, software metrics, testing, version control systems, etc. The proposed course has been evaluated with positive results (Chatzigeorgiou et al. 2016), and it is in accordance with the findings of the Joint Task Force on Computing Curricula of the IEEE Computer Society and the Association for Computing Machinery

(ACM) (LeBlanc and Sobel 2004), where a set of guidelines for effective education activities have been established. These guidelines emphasize the need to focus on professional issues necessary to begin practice as a software engineer and the need for students to complete tasks that involve both individual work and tasks that require collaboration among peers. Having this in mind, students were divided into small groups as described in (Petkovic et al. 2006), with the exception that they were left alone to form the groups. This approach seemed more appropriate to the Arabic or the Greek cultures, where students tend to lean toward the existing bonds among them.

The rest of the entry is outlined as follows: section “[Introduction](#)” presents an outline of the proposed course; the detailed structure along with the introduced software engineering concepts and the activities carried out at each step. Section “[The Course](#)” provides some guidelines for an effective application of the proposed course, and section “[Guidelines for Delivering the Course](#)” provides the final conclusions.

The Course

Learning Outcomes

The proposed course aims at introducing software engineering concepts and techniques in the context of Android development. The course can be delivered either in an advanced undergraduate or a postgraduate program. In case students have a background in both areas (software engineering and Java/Android development), the objective is to highlight that mobile application development can benefit from the adoption of best practices as learned in a software engineering course. In case students lack background in any of the involved areas, the course can also serve as an introductory seminar for the corresponding topic, given that it includes theoretical aspects as well as lab activities.

The short course is in agreement with the 2013 Curriculum Guidelines for undergraduate programs in computer science by ACM (2013) where Platform-Based Development (PBD) has been elevated to a Knowledge Area (KA) in the

Computer Science Body of Knowledge. The guidelines suggest that electives should be offered (in the area of programming interactive systems) covering the needs for specific programming paradigms and mobile development and these are designated as “high-demand” courses. Within the ACM report, it is noted that platform-based development as a general skill of developing with respect to an Application Programming Interface (API) or a constrained environment is directly related to other knowledge areas such as Software Development Fundamentals (SDF). As a result, the relationship between mobile development and software engineering is profound.

According to the constructive alignment approach (Biggs and Tang 2011), it is important to start reasoning about the outcomes that a planned course aims at achieving and then align the teaching and assessment strategies to those explicitly stated outcomes. Learning outcomes are statements of what a learner is expected to know, understand, and/or be able to demonstrate after completion of a lecture, course, or entire program. Compared to teaching aims or objectives, outcomes offer the advantage of being more precise, clearer, and easier to compose (Kennedy et al. 2006).

We formulate the learning outcomes of the proposed short course as follows, placing them in the appropriate knowledge and cognitive process dimension of the revised Bloom’s taxonomy (Krathwohl 2002) in Table 1:

1. Explain the benefits from applying software engineering practices to Android development.
2. Apply design principles and design patterns in Android applications.
3. Identify and resolve design issues in Android applications.

Informed choices regarding the curriculum have to clearly define the desired Information and Communication Technology (ICT) skills, besides the underlying knowledge area(s) and learning outcomes. A tool that can be used for this purpose is the Skills Framework for the Information Age (SFIA), which provides 6 categories and 19 subcategories including 96 ICT-specific skills in total (SFIA Foundation 2015). These skills are defined quite generally and independently of the underlying knowledge areas, so that they are transferable to different ICT domains/disciplines. In addition to the general definition, SFIA provides a definition of each skill across the following seven levels of responsibility (that apply in each case): (1) follow; (2) assist; (3) apply; (4) enable; (5) ensure and advise; (6) initiate and influence; and (7) set strategy, inspire, and mobilize. Utilizing a tabular approach (Herbert et al. 2013), the main SFIA skills that the proposed course aims at are presented in Table 2.

The course is structured around a base Android application that is gradually enhanced over 13 consecutive steps. At each step a different software engineering concept, practice, or technique is introduced which is then exemplified through additions to the functionality of the application or restructuring of its design.

In accordance to Keller’s Motivation Theory (Keller 1983), the course is designed in order to promote learning by increasing students satisfaction and attention. A feeling of satisfaction is achieved by providing students with opportunities to apply on a small, but real Android application the newly learned knowledge and the interest of the students is engaged by interleaving different software engineering practices and techniques on the same example. Since the course is structured

Applying Software Engineering Principles in Android Development, Table 1 Course learning outcomes in terms of the revised Bloom’s taxonomy

Knowledge dimension	Cognitive process dimension					
	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
A. Factual knowledge		(1)				
B. Conceptual knowledge		(1)	(2)	(3)		
C. Procedural knowledge			(2)	(3)		
D. Metacognitive knowledge						

Applying Software Engineering Principles in Android Development, Table 2 Targeted SFIA skills of the course

Category ~ Subcategory	Skill	Level	Code*
Solution development and implementation ~ Systems development	Programming/software development (<i>The design, creation, testing and documenting of new and amended Android programs</i>)	2 – assist 3 – apply 4 – enable	PROG
Solution development and implementation ~ Systems development	Systems design (<i>The specification and design of information systems to meet defined business needs. The identification of concepts and their translation into implementable design</i>)	2 – assist 3 – apply 4 – enable	DESN
Strategy and architecture ~ Technical strategy and planning	Software development process improvement (<i>The provision of advice, assistance and leadership in improving the quality of software development, by focusing on measurement</i>)	5 – ensure, advise 6 – initiate, influence	SPIM
Strategy and architecture ~ Technical strategy and planning	Methods and tools (<i>Ensuring that appropriate methods and tools for the development, testing and maintenance of systems are adopted</i>)	4 – enable 5 – ensure, advise	METL

*Refers to the unique skill code in the SFIA Framework

around a central lab activity which is gradually enhanced, it adheres to the learning theory of “Learning by Doing” which is one of the most well-known theories (Dewey 1938). Instructors can decide on the importance/time that should be placed on the theoretical presentation of each software engineering concept or technique and the corresponding hands-on assignments, depending on the subjects’ background. The particular contents of each step are discussed in the next section.

Course Structure and Activities

As already mentioned, the proposed course is structured as a series of incremental additions to an initial Android application with the goal of introducing a different software engineering principle, concept, or technique each time. The outline of the course is shown in Table 3, depicting the corresponding students’ activity in each step, the functionality of the resulting Android Java application as well as the introduced concept. A detailed presentation of the introduced software engineering concepts, as well as the corresponding activities, is provided in the following paragraphs.

Step 1: MVC Pattern

The Model-View-Controller architecture (or pattern) is fundamental to various domain-specific

architectures that entail a significant amount of interaction with the user (Ghezzi et al. 2002). The architecture suggests the use of three different components: (1) the model that manages the data of the application domain, (2) the view that takes over the graphical display of the model, and (3) the controller that interprets user actions and coordinates the view and the model. A partial illustration of the MVC pattern can be achieved with the use of `ListView` objects in Android, which show items in a vertical scrolling list. A `ListView`, as any other View in Android, is built as a separate layout XML file and plays the role of the View component in MVC. Lists are populated by retrieving data from appropriate adapters which essentially control the content displayed in the list and the way it is displayed (Controller component of the MVC). The data itself can reside in a separate object as in the proposed example and constitutes the Model component of MVC. The separation of components according to MVC is shown graphically in Fig. 1.

Step 2: Externalization of Resources

Android encourages the application of a valuable practice, namely, the externalization of non-code resources like images and string constants or even entire layouts. Keeping resources separate from source code enables easier maintenance,

Applying Software Engineering Principles in Android Development, Table 3 Course structure

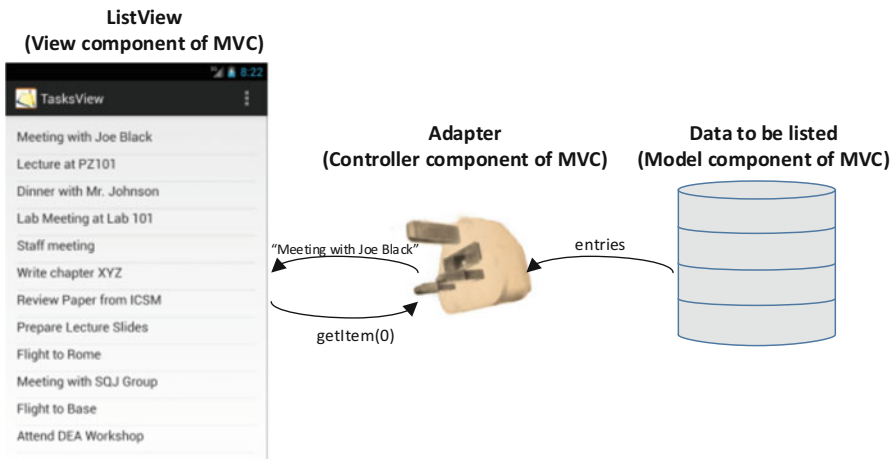
	Students' activity	Functionality of the resulting software	Introduced software engineering concept/technique
1	Downloading of initial version	Listing of future appointments in ListView	Model-View-Controller pattern Ghezzi et al. (2002)
2	Introduction of Android activity	Addition of input screen	Externalization of resources Mednieks et al. (2012)
3	Development of task hierarchy	Submission of tasks to ListView	Use of inheritance for modeling similar entities Liskov substitution principle Liskov and Wing (1994)
4	Intent handling	Display of task description and date and selection of appropriate color for each task type	Use of polymorphism. Open-Closed Principle Martin (2003)
5	Preservation of state between invocations of an activity	Display of multiple tasks in the ListView	Singleton design pattern Gamma et al. (1995)
6	Use of TreeSet structure for ordering	Ordering of tasks based on their date	Dependency inversion principle (use of TreeSet class – implementation of the Comparable interface)
7	Installation of metrics plugin. Examination of metric values	No change. Assessment of quality	Software metrics and their use for software quality evaluation. Software ageing
8	Identification of code smells	No change. Assessment of quality	Code smells (large method)
9	Unit test preparation	No change	Unit testing. Regression testing
10	Refactoring application Execution of unit tests	No change. Design improvement	Refactorings as a means to improve software. (extract method refactoring)
11	Addition of code. Identification of smell. Refactoring application	Setting task description text to title case	Smells + refactorings (extract method/move method)
12	Committing to a Git repository	No change	Distributed version control
13	Uploading to a common remote repository. Downloading by different students, edits, and merging. Viewing history	Any modification is acceptable	Collaborative software development

updating, and management. For example, internationalization can be easily supported having Android automatically select the appropriate resource values depending on the device's specific language or country, without having to modify the source code that manipulates these resources. The students' activity in this step consists in the creation of a simple Activity (by interacting with the layout) and placing emphasis on the externalization of string values that specify the text to be displayed for each graphical component. The corresponding process is depicted graphically in Fig. 2. After changing the introduced activity to a launcher activity, when the application starts, it

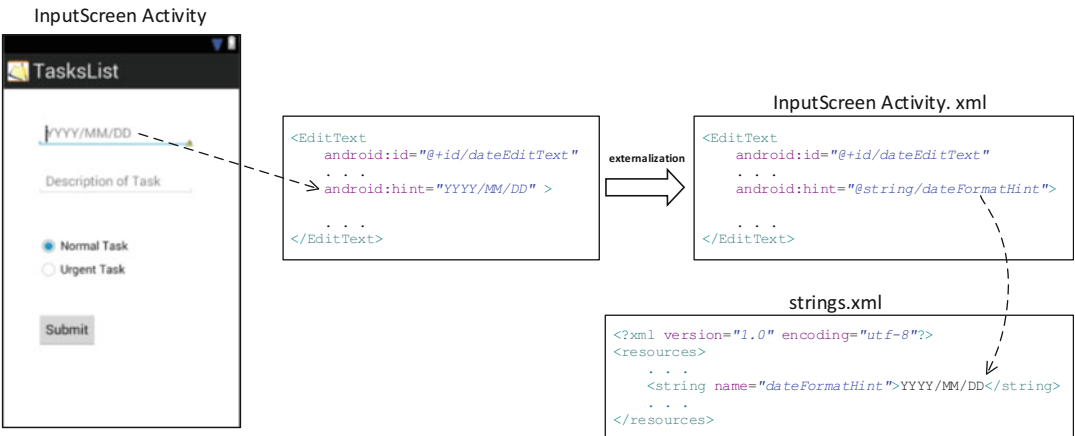
displays the simplified input form for adding new tasks (without any functionality in the submit button so far).

Step 3: Use of Inheritance for Modeling Similar Entities

The next step in the proposed example consists in the addition of functionality to the "submit" button, so that whenever a new task is added, it will be displayed on the `TasksView` activity. The essence of this step is not the linking of a button to a class method – which is rather straightforward – but rather the need to highlight that classical object-oriented concepts, like inheritance



Applying Software Engineering Principles in Android Development, Fig. 1 Illustration of the Model-View-Controller pattern in the context of a ListView



Applying Software Engineering Principles in Android Development, Fig. 2 Introduction of Activity and externalization of strings

and abstraction, can be applied to Android applications as in any other kind of project that the students learned in the corresponding object-oriented programming courses. Once the “submit” button is pressed, the information concerning the added task (date, description, and urgency in this simplified example) should be transferred to the `ListView`, along with an intent that will cause the appearance of another activity’s view (Mednieks et al. 2012). A large number of Android developers would simply transfer this information in the form of individual strings, missing the

opportunity of taking advantage of an appropriate Task hierarchy. All pieces of information can be embedded into an appropriate Task object, whose class will designate the actual type of the task. Apart from the structural improvement to the source code that improves readability, the use of an inheritance relationship as shown in Fig. 3 will enable the use of polymorphism and the adherence to the “Open-Closed Principle” as it will be shown later. To make the distinction more clear, we assume that for urgent tasks the corresponding background in the `ListView` will be red (blue

for NormalTasks) and that the description of each task will have as prefix the urgency of the task (“Urgent,” “Normal”).

In order to have task objects be conveyed by the intent that will be emitted, the corresponding Task classes should implement the `Serializable` interface. It is reminded that this is a marker interface, which means that it does not contain any methods that have to be implemented. A class implements this interface simply to indicate that its non-transient data members can be written to an output stream. The abstract superclass in Fig. 3 declares two abstract methods which are implemented in a different way in each of the subclasses. The functionality of the application after the completion of this step enables the user to add a new task and view the corresponding description in the `ListView`. Only a single task can be viewed at this point.

The class related to the input screen – whenever the submit button is pressed – reads the information in the input text fields and, depending on the selection of the radio buttons, instantiates either a `NormalTask` or an `UrgentTask` object. Then, an `Intent` is sent to the Android system defining explicitly the class that should be invoked (`.class`), and the instantiated task object is passed within the intent.

The `TasksView` class (containing the `ListView` object) receives the intent and retrieves its content without knowing which kind of task has been included. The received task

object is assigned to a Task reference and transferred to the corresponding data model.

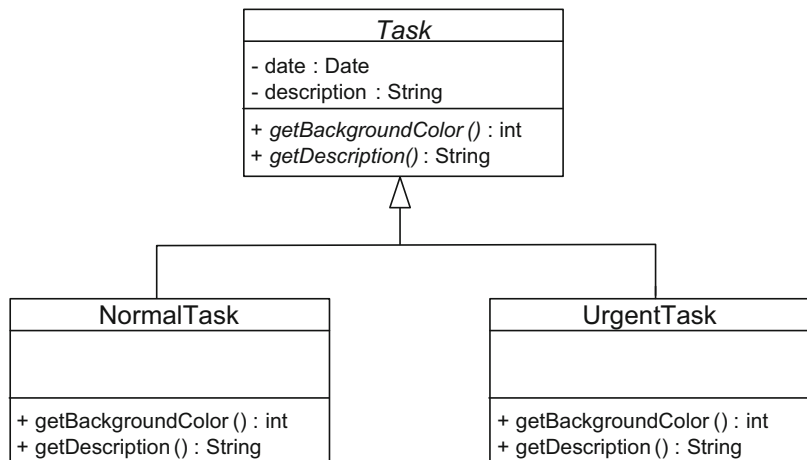
At this point, students should be reminded about the “Liskov Substitution Principle” (Liskov and Wing 1994) according to which “derived types must be completely substitutable for their base types.” In other words, any method, class, or system that handles objects of a superclass should operate properly even when objects of subclasses are used. In the context of the examined application, a reference to the Task class can receive an object of any of its subclasses, namely, `NormalTask` or `UrgentTask` objects, since a generalization is an “is-a” relationship meaning that `NormalTasks` and `UrgentTasks` are also Task instances. This concept is illustrated in Fig. 4.

Step 4: Polymorphism and Open-Closed Principle

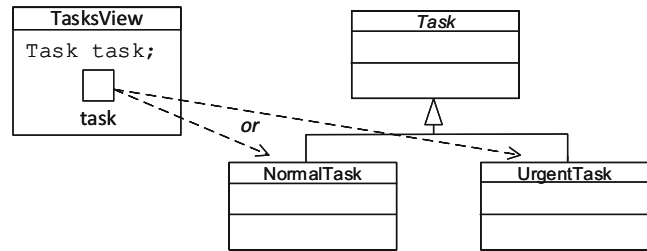
The real benefit from the use of polymorphism becomes evident when the handling of the received intent is performed in the `TasksView` class in order to display the newly added task. The `TasksView` retrieves the Task object from the intent and stores it in the corresponding data model. Within the adapter method which is responsible for filling in the corresponding line items of the `ListView`, the color for the background of each task is obtained by a call of the form:

```
Task task = (retrieved from the
intent)
. . .
int color = task.getBackgroundColor();
```

Applying Software Engineering Principles in Android Development,
Fig. 3 Task hierarchy



Applying Software Engineering Principles in Android Development, Fig. 4 Liskov Substitution Principle in the context of the examined application



Method invocation `task.getBackgroundColor()` is a polymorphic method call, since dynamic binding will be employed to invoke the appropriate method of the corresponding Task subclass, depending on the actual type of the object to which reference `task` will be pointing to at runtime. Students get the opportunity to understand that this essential feature of object-orientation – which is rarely employed in Android applications – can be easily integrated with the rest of an application’s functionality.

At this point, the “Open-Closed Principle” of software engineering (Martin 2003) according to which “software modules should be open for extension (of functionality) but closed to modification (of existing source code)” can be reintroduced. The client of the Task hierarchy which is the Adapter/View part of the system can be extended (e.g., new kinds of Tasks can be added with different functionality in terms of background color or description formatting) without the need to modify even a single line of the code that handles the tasks. The “Open-Closed Principle” is illustrated in Fig. 5.

Step 5: Singleton Design Pattern

The application so far suffers from a rather serious drawback: only one task is displayed regardless of how many are introduced in the input screen. The reason is that whenever the `TaskView` activity is invoked by a new intent it leads to the construction of a new adapter associated therefore with a new data model, and previous tasks are lost. In other words there is no preservation of state between activity invocations.

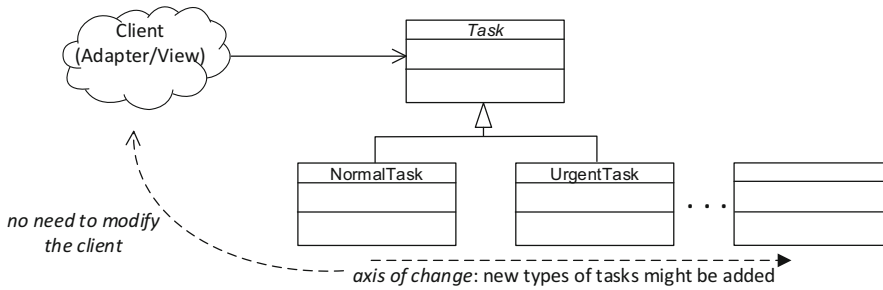
Although in a real application data would be directly stored into a database to allow persistence, at this point it would be very useful to remind the notion of design patterns as a means

of resolving commonly recurring problems by reusing previous experience (Gamma et al. 1995). In this particular case, the Singleton design pattern offers an elegant solution to the problem of data preservation. The goal of this pattern is to ensure that only one instance of a class is created and that a global access point is provided to that object (Gamma et al. 1995). Turning the Model class which holds the list of tasks to be displayed to a Singleton ensures that at any time the same, unique data model is used. In terms of functionality, the application allows the display of numerous tasks.

Step 6: Dependency Inversion Principle

So far, the application displays tasks in the order in which they have been added to the input screen. Obviously, there is a need for ordering tasks according to their date. This can be easily accomplished employing a data structure in which stored elements are automatically ordered. An appropriate Java data structure is the `TreeSet` where elements are retrieved based on their natural ordering. For any domain-specific class like the Task class the developer should specify the way in which tasks should be ordered by implementing the `Comparable` interface and overriding the `compareTo()` method (or alternatively by providing an appropriate `Comparator`). In this particular case, the `compareTo()` implementation can simply delegate the responsibility of comparing two tasks to their included `Date` objects. The resulting functionality at this point is a listing of tasks according to their date, i.e., closer tasks in time are displayed first.

While this is a rather widely known technique to Java developers, it would be important to emphasize that the designers of Java essentially adopt the “Dependency Inversion Principle”



Applying Software Engineering Principles in Android Development, Fig. 5 Open-Closed Principle in the context of the examined application

(DIP) (Martin 2003) in this context. The DIP principle states that “High-level modules should not depend on low-level modules. Both should depend on abstractions”. In other words, high-level modules such as the implementation of the `TreeSet` class, which should be agnostic of the particular items that will be stored in the structure, should be decoupled from the corresponding classes, and this is achieved by declaring that `TreeSet` handles `Comparable` objects. Any class, whose objects should be stored in a `TreeSet` will therefore have to comply with the `Comparable` interface and provide an implementation to its single method taking care of the comparison between two objects. The philosophy of the DIP principle in the context of the `TreeSet` is illustrated in Fig. 6. The principle is of extreme importance for enabling the development of maintainable systems and especially APIs, and this sets an excellent opportunity for introducing the resulting benefits of DIP application to the students.

Step 7: Metrics for Software Quality Assessment

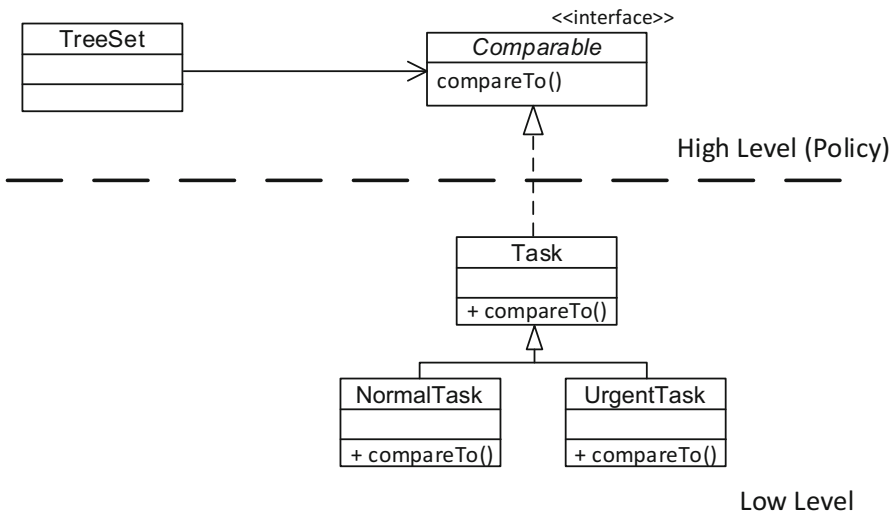
At this point the application has a reasonably large number of lines of code and methods. Moreover, the continuous evolution in terms of functionality enhancements highlights that Android applications are by nature evolving software projects. In order to assess whether the qualities of the underlying design deteriorate or not over time, software metrics can be employed as in any other type of software system. Students should be reminded about the challenges associated with software maintenance and the possibility of software

ageing (Parnas 1994). From the perspective of quality assurance, monitoring software qualities by means of appropriate software metrics can offer significant help in preventing the accumulation of the so-called technical debt (Cunningham 1992).

At this step students should install a metrics collection and analysis tool, preferably one that is integrated into the employed IDE in order to assist the next steps related to preventive maintenance. Students can obtain a first impression and reason about the properties of the design by assessing metrics related to size, complexity, coupling, and cohesion. Indicative results are shown in Table 4. It is important to discuss the concept of aggregating metric values from one software level (e.g., methods) to the next (e.g., class, package, or system).

Step 8: Code Smells

According to Fowler (1999), deeper problems in the system structure often manifest themselves in the form of easily identifiable code smells, i.e., surface indications that something might be wrong at the code or design level. Hints for the presence of several smells can be provided by excessive metric values or values that deviate from the mean. As an example it can be observed that method `getView()` in the `TasksAdapter` class is much longer than the rest of the methods in that class and has a higher complexity and a larger number of parameters, a potential indication of a “long method” smell (despite the fact that in this case the smell is rather weak and presented only as an example). A long



Applying Software Engineering Principles in Android Development, Fig. 6 Dependency Inversion Principle in the context of the examined application

Applying Software Engineering Principles in Android Development, Table 4 Sample metrics related to the Android application at the method and class level

Class/method		LOC (lines of code)	Number of parameters (per method)	CC (cyclomatic complexity per method)
TasksAdapter		18	1.0	1.167
	TasksAdapter()	1	0	1
	addTask()	1	1	1
	getCount()	1	0	1
	getItem()	1	1	1
	getItemId()	1	1	1
	getView()	13	3	2

method refers to a piece of code that is large in size, noncohesive, and relatively complex. A method with these symptoms might be difficult to comprehend, modify, test, and reuse (although for the size and complexity of the examined applications, these problems might seem too distant).

For the case of the long method, the designer should assess the intensity of the problem. This is often related to whether the method takes over more than one responsibilities. Different responsibilities might be subject to different “axes of change,” implying that part of a method’s body might be modified although the rest of the method’s functionality should remain unchanged, often leading to the propagation of errors from one

part to another. As an example, consider the method `getView()` of class `TasksAdapter` which has already been identified by the application of metrics as a larger and more complex method, in comparison to the rest of the methods in that class. Although its logic is quite simple, it contains two distinct responsibilities which are highlighted in the code fragment of Fig. 7: (a) the inflation of a new view object from the corresponding XML resource (in this case a single task list item containing the description and date of each task) and (b) the population of this view based on the information that can be retrieved from a task object. This case could be regarded as a symptom of the “long method” smell.

```

public View getView(int index, View view, ViewGroup parent) {
    if (view == null) {
        LayoutInflater inflater = LayoutInflater.from(parent.getContext());
        view = inflater.inflate(R.layout.tasks_list_item, parent, false);
    }

    Task task = model.getItem(index);

    TextView descriptionTextView =
        (TextView) view.findViewById(R.id.description_view);

    descriptionTextView.setText(task.getDescription());

    TextView dateTextView = (TextView) view.findViewById(R.id.date_view);

    dateTextView.setText(task.getDateText());

    int color = task.getBackgroundColor();

    descriptionTextView.setBackgroundResource(color);
    dateTextView.setBackgroundResource(color);

    return view;
}

```

inflates view from the specified xml resource

populates the view with retrieved task data

Applying Software Engineering Principles in Android Development, Fig. 7 Pseudocode for getView() method highlighting the different functionalities

Step 9: Unit Testing

According to the famous quote by Dijkstra, the aim of testing software systems is to reveal the presence of errors which in turn might lead to system failures (Dahl et al. 1972). One of the most effective approaches for testing large and complex systems consists in the execution of unit tests, where the goal is to compare the expected behavior of individual software modules (e.g., classes) to their actual one. The most important benefit from the construction of a set of unit tests is the ability to perform regression testing, which means that the system can be tested for possible errors after any slight modification, providing a certain degree of confidence that maintenance has not introduced additional errors.

At this step of the proposed course, students are asked to generate test cases for the TasksAdapter class, prior to any attempt of improving the class structure, since a smell has been identified in one of its methods. The testing framework of choice to support the preparation

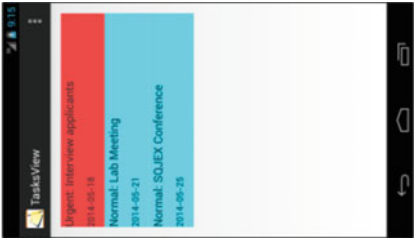
and execution of test cases is JUnit (<http://junit.org>) which is an open-source, widely acknowledged and easy-to-use unit testing environment integrated into the Eclipse IDE. Test cases are written in the form of method invocations with selected parameter values and known results. A test case succeeds if the examined method fed with the selected parameters behaves as expected.

In this particular case, the goal is to test the behavior of the getView() method of the TasksAdapter class. However an adapter is always associated with the corresponding Activity containing a ListView object, so the goal is to add a task to the ListView and inspect whether the getView() method returns the correct task. To perform tests for activity unit testing, one should create a subclass of the ActivityUnitTestCase and initiate an Intent to trigger the desired activity (Android Developers 2013). The test case that contains a unit test for the getView() method of class TasksAdapter is shown in Fig. 8.

Code Under Test (Adapter)

```
public class TaskAdapter extends BaseAdapter {  
    private Model model;  
    ...  
    public View getView(int index, View view,  
        ViewGroup parent) {  
        //constructs a view for each listView item  
        //and populates it with information  
        //retrieved from the corresponding Task  
    }  
}
```

Activity with ListView



Test Case (unit test targeting getView () method of the Adapter)

```
public class TaskViewTest extends ActivityUnitTestCase<TaskView> {  
    private TaskView activity;  
    private ListView listView;  
    ...  
    protected void setUp() throws Exception {  
        super.setUp();  
        Date date = ... //create a Date object 2014/05/21  
        Task newTask = new NormalTask(date, "SampleTask");  
        //initiate the TaskView activity feeding it with the newTask  
        Intent intent = new Intent(  
            getInstrumentation().getTargetContext(), TaskView.class);  
        intent.putExtra("Task", newTask);  
        startActivity(intent, null, null);  
        //retrieve the activity and the enclosed listView object  
        activity = getActivity();  
        listView = activity.getListView();  
    }  
    //test whether the listView (i.e. the associated adapter)  
    //retrieves the correct task  
    public void testGetView() {  
        Task task = (Task) listView.getItemAtPosition(0);  
        assertEquals("Normal: SampleTask", task.getDescription());  
        assertEquals("2014-05-21", task.getDateText());  
    }  
}
```

Applying Software Engineering Principles in Android Development, Fig. 8 Unit testing for Android activity/adapter

Step 10: Refactoring Application (Extract Method)

Now that the source code is equipped with test cases, developers can attempt to improve the design by applying appropriate refactorings. After any change, the test cases can serve as a checkpoint against which functionality can be verified. A refactoring is a way to improve the internal structure of software without changing its observable behavior (Fowler 1999). In most cases, refactorings are applied in order to resolve code smells that have been identified. Refactorings have been widely embraced by software developers mainly because of the simplicity in applying them. Currently, numerous IDEs provide support for the automatic application of refactorings relieving the designers from the burden of their mechanics (Murphy-Hill et al. 2009). Although the impact of a single refactoring might seem limited, the cumulative effect of successive refactorings on design quality can be significant.

Test cases can guarantee (with a certain degree of confidence) that any modification to the design has not altered the functionality of the methods. Returning to the “long method” smell observed for the `getView()` method of the `TasksAdapter` class, the appropriate refactoring would be to split the existing method in two more cohesive methods. According to Fowler’s catalog (Fowler 1999), this corresponds to the “Extract Method” refactoring, whose goal is to “turn a fragment of code into a method whose name explains the purpose of the method.” For the `getView()` method, the functionality related to the retrieval of information from the `Task` object in order to populate the view’s contents can be extracted as a separate `populateView()` method, which will be invoked by the original method as shown in Fig. 9. The Eclipse IDE can automatically apply the Extract Method refactoring by simply designating the fragment of code that needs to be extracted and automatically identifies the parameters that have to be passed from the original to the extracted method. The application of the JUnit tests validates that the application of the refactoring did not break the existing functionality. As it can be deduced, the resulting methods are smaller, less complex, and more cohesive than the original one.

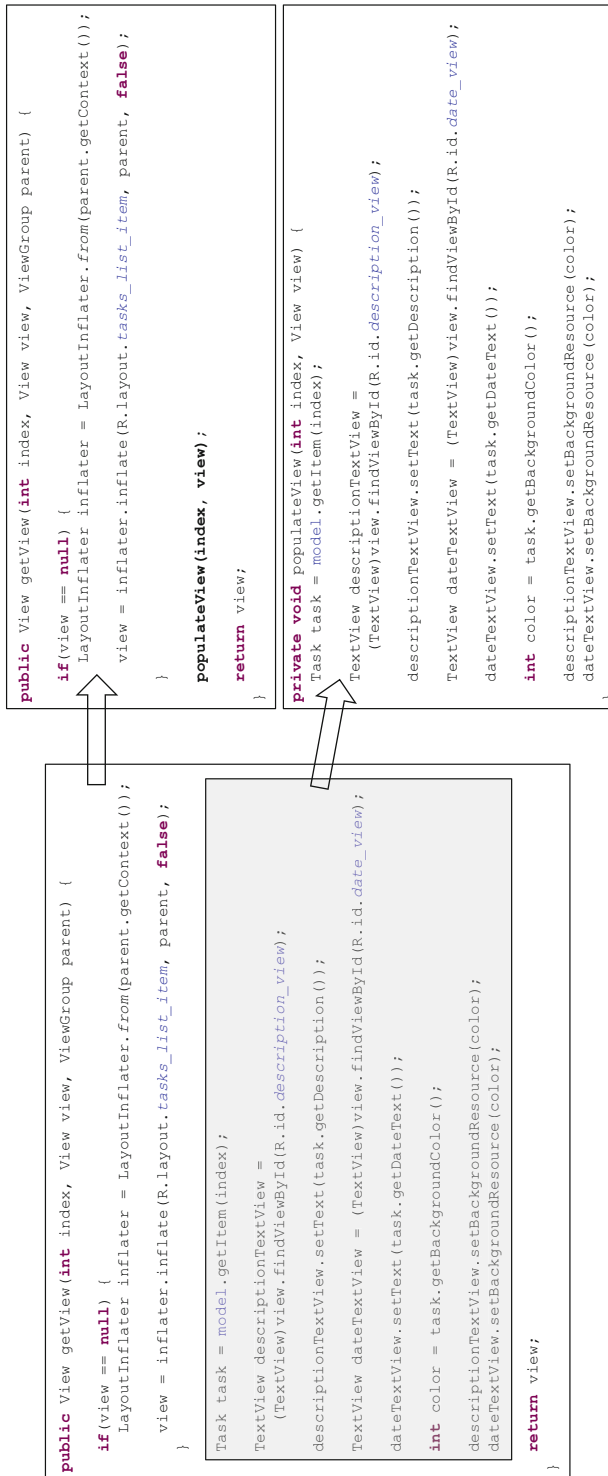
Step 11: Refactoring Application (Extract Method + Move Method)

As software evolves, additional functionality is gradually added to address the needs of clients. Let us assume that the `populateView()` method of the `TasksAdapter` has been enhanced in order to display the description of the forthcoming tasks in title case (Fig. 10). The method’s code has once again become large and relatively complex, and since the conversion of a string to title case is a rather distinct responsibility, it should be extracted as a separate method by applying the Extract Method refactoring as previously (Fig. 10).

However, in this case the extracted method `convertToTitleCase(Task task)` has nothing to do with the `TasksAdapter` class in which it resides. The method accesses only methods from another class, and this is a clear symptom of the “Feature Envy” smell, which according to Fowler (1999) exists when “a method seems more interested in a class other than the one it is in.” The appropriate refactoring to address this design problem is the “Move Method” which consists in moving the method to the target class. In this case the `convertToTitleCase()` method should be moved to the `Task` class, where it also belongs conceptually, since the ability to format the description of a task is related to the task itself, rather than any other class. Eclipse IDE provides support for this refactoring and automatically identifies the `Task` class as the target for moving the method. The existence of the unit tests enables the validation that the application of the refactoring keeps the functionality intact. The series of two refactorings is graphically illustrated in Fig. 10.

Step 12: Distributed Version Control Systems

Software systems are multi-version projects that continuously undergo adaptive, corrective, and perfective maintenance. Even the simplified example outlined in this entry has evolved over a number of versions. An essential part of each software project is its configuration management which deals with tracking and controlling changes in software artifacts, including revision control.



Applying Software Engineering Principles in Android Development, Fig. 9 Extract Method refactoring

Version Control Systems (VCS) refer to software that allows the management and monitoring of changes that occur in any artifact of a project during its initial development or maintenance (Spinellis 2003). Version control offers significant benefits to the development team, including the ability to retrieve and compare either the entire project or individual files created at any time point, access to a log of all past changes, and under certain conditions support for collaborative software development.

Nowadays, it is hard to find an industrial project that is not backed up by a VCS, and thus it would be extremely beneficial to introduce students to the corresponding practices. It should be mentioned that the use of a VCS exhibits several challenges which cannot be covered by a short course. In the proposed example, the goal is to highlight the key benefits from using a VCS. Due to its widespread adoption, emphasis is placed on distributed VCS such as Git (<https://git-scm.com/>). Although distributed VCSs can also share a common remote repository, they adopt a peer-to-peer approach where each peer has his own full-fledged repository with complete history and the use of version tracking does not depend on access to a central server. The Git functionality can be accessed through the EGit Eclipse plug-in and thus be integrated in the IDE used for development.

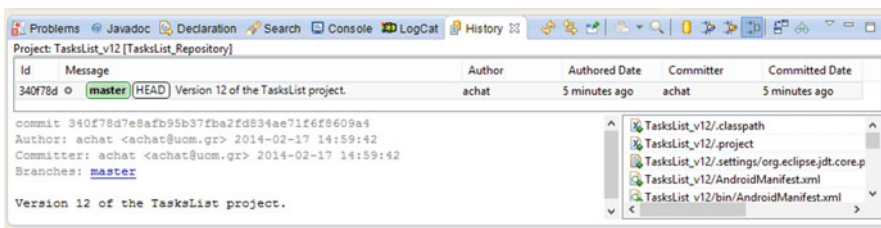
At this step of the course, students are asked to install EGit, create a Git repository, and commit the project to the repository. Details about EGit usage can be found at the corresponding EGit documentation (<http://www.eclipse.org/egit/documentation>). Students are asked to enter a log message that will be attached to each individual

commit. Once the commit is performed, students will be able to track the history of the project as shown in Fig. 11. Students can be introduced to the concept of the main development branch (master), the HEAD pointer referencing the branch that the user is currently on, the importance of good commit messages, and the unique identifier assigned to each Git commit object in the form of a SHA-1 hash value.

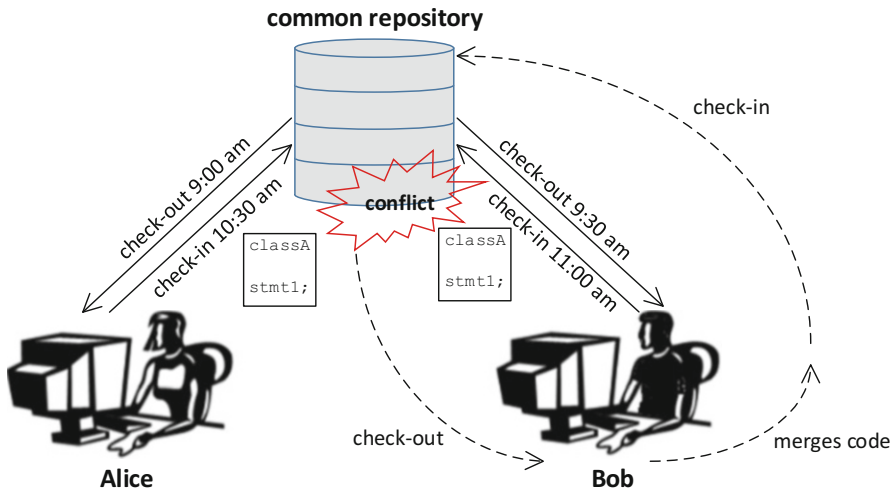
Step 13: Collaborative Software Development

Contemporary software development teams consist of members which often are not located in the same geographical area and might even be working at different time zones. To enable the collaboration between multiple developers, VCSs require the use of a common, remote repository that can be used for sharing software artifacts to the rest of the team. A popular hosting provider for Git projects is GitHub (<https://github.com/>) and can be used for the proposed course since public repositories are hosted for free. The instructor (or any student) can create a repository and add fellow students as collaborators to the project (such a project has been created for this course at GitHub).

Students can now start experimenting with collaborative software development based on the Android project that has been developed so far. For example, the instructor can push his own Android project to GitHub and allow students to clone the existing version. Students can simulate the automatic resolution of conflicts when two developers modify at different times two different files and commit and push them to the remote repository. The system will automatically deduce the reasonable course of action which is to accept



Applying Software Engineering Principles in Android Development, Fig. 11 Use of the local repository in EGit



Applying Software Engineering Principles in Android Development, Fig. 12 Handling of conflicts during collaborative software development

and merge the changes. However, in the case when two students make edits to the same file, a conflict will be raised when the second student attempts to commit and push his work. The second student will be informed about the conflict and be prompted to choose one edit over the other or revise the affected lines entirely (such a case is illustrated in Fig. 12). The fact that a VCS can handle similar situations can be an extremely valuable asset in mobile software development.

Guidelines for Delivering the Course

The proposed short course has been delivered to three groups of undergraduate and postgraduate students at two different institutes (Table 5). The course has been evaluated: (a) by performing a student satisfaction survey, (b) by summatively assessing students' performance, (c) by investigating whether the proposed course modified the students' career interests, and (d) by employing assessment by peers based on rubrics. The results are presented in detail in a previous paper (Chatzigeorgiou et al. 2016) and indicate that such a short course is capable of increasing student's interest on Android development as well as

their awareness of the importance of software engineering concepts on mobile application software development. Based on the accumulated experience and the results of the course's evaluation, some guidelines are provided for a more successful teaching.

Utilize a Wiki Page for Supporting the Teaching Process and Communication

A wiki is a web application that gives the chance to collaborate online (Parker and Chao 2007), while it supports online classroom management and offers peer and self-assessment features (Schwartz et al. 2004).

In order to support the teaching process and the communication among students and instructor, a wiki page was developed when delivering the proposed course using as a development environment "Wikispaces" (www.wikispaces.com). Moreover, in order to develop and conduct the online assessment (multiple choice questions) in this course, the "ThatQuiz" online examination system was used (available through <http://www.thatquiz.org>).

The wiki page that was developed for the proposed course can be viewed from the following perspectives:

Applying Software Engineering Principles in Android Development, Table 5 Details of groups to which the course has been delivered

Group ID	Degree	Department	University/ college	Enrollment	Prior Java course	Prior Android course	Prior SE course
1	Undergraduate	Information Technology	Institute 1	16	Yes	No	No
2	Undergraduate	Computer Science	Institute 2	30	Yes	No	No
3	Postgraduate	Computer Science	Institute 2	12	Yes	No	Yes

- *A content delivery system*: providing course objectives, guidelines for the required software infrastructure, and a course outline. The course outline consists of hyperlinks to webpages that provide an overview of the objectives for each step, an explanation on how these objectives can be achieved, additional educational material such as PowerPoint presentations, as well as a link to download the appropriate source code example that is needed for the corresponding step.
- *An online examination platform* that gives students the chance to download the exam as a document file that can be printed and answered offline or connect to the online examination system and get immediate feedback for their answers.
- *A forum* allowing online discussion where participants can hold conversations, post messages, and questions regarding the course.

Take into Account Students' Prior Knowledge

To ensure a smooth progression of the course, the instructor should be aware in advance of the students' level of knowledge and skills in both software engineering and Java development. Ideally, the proposed course should be delivered right after a software engineering course, or at least a course related to Object-Oriented Software Development.

Provide the Appropriate Time for Students to Assimilate the Content

Covering all of the introduced concepts and techniques and carrying out the related activities require no less than 12–16 teaching hours, depending on the students' background.

Provide the Necessary Software Infrastructure

The course relies on a multitude of tools such as the Eclipse IDE for programming, Android SDT, tools for unit testing, metrics calculation, refactoring application, version control, and possibly computer-aided software engineering (CASE) tools. Using a lab where the workstations are ready to use can help students focus on the learning goals. Also, running the course in a lab where all workstations can be accessed from each other or from a central server is important, since it might be often required to deliver one working version of the project to all students.

Try to Keep Students Synchronized

The course is structured as a series of small incremental steps, exactly as it would occur during the actual development of a software project in a small team. Given that the students have often a completely different working pace from each other, it is really challenging to keep them synchronized, but at the same time, it is important in order for them to remain focused.

Try to Monitor Students' Participation

As in any other programming course, student participation should be a key objective of the course. Students can actively participate by asking questions, providing feedback on encountered problems, suggesting alternative implementations and even developing a solution, and implementing and sharing it with the rest of the students' groups. However, the multitude of introduced concepts, tools, libraries along with the compile, runtime, or emulator errors that can arise in Android hinders student's participation

who find themselves in the process of “making their own project work.” The instructor should be aware of this issue and resolve persistent problems so that students can take on the essence of the delivered material.

Conclusions

The popularity of mobile devices running the Android OS and the bright prospects for mobile application developers in the IT market has raised students’ interest in Android development courses in higher education institutes around the world. However, Android software systems are becoming increasingly complex, and designing relevant courses is not an easy task. In order for an Android development course to be successful, it must combine Android programming with state-of-the-art software engineering content.

In this entry, a short course is introduced aiming at illustrating selected software engineering principles, concepts, and techniques in the context of Android application development. It must be noted that there is no need for an instructor to strictly follow the order, number, and content of the steps analyzed. Based on the students’ prior knowledge and the particular goals of each curriculum, the short course can be modified accordingly. As an example, the course could be extended to a full semester course by adding an introduction to the basics of Android development (e.g., Android components and life cycles, building of views, etc.) as well as additional steps illustrating the use of additional software engineering concepts or more cases of the already examined ones (i.e., more design patterns, metrics, and refactoring types). Another axis along which the course can be extended concerns the functionality of the application itself, which can be turned into a much more complicated one, involving 2D graphics, storage in a database, and communication with a server. However, it should be borne in mind that the essential goal of such a course is not an introduction to Android programming per se, but rather the leveraging of well-established software engineering practices to the benefit of mobile application development.

Cross-References

- [Teaching Software Design Techniques in University Courses](#)

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Architectural Pattern

- [Teaching Software Design Techniques in University Courses](#)

Art Component of Remote Training

- [Art Component of Remote Training in Russian Universities](#)

Art Component of Remote Training in Russian Universities

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Synonyms

[Art component of remote training](#); [e-learning](#); [Remote training](#)

The e-learning has started to develop in Russia since the beginning of the 2000s. The e-learning service consumers are as follows:

- Companies that need to systematically provide a large number of seminars devoted to their products and services to a large number of employees. Banks, financial corporations and insurance companies may be referred to as such types of companies, where all of them have rather large and simultaneously constantly changing product lines. In this regard, it is rather impossible to constantly develop and conduct in-person product trainings since it is too expensive and slow.
- Companies with standardized technologies and procedures. They have a library of standard courses, for instance, fire safety courses, or

courses on how to process some documents. These courses usually require minimal changes over a long period of time. Indeed, this approach saves the company's money and staff's time significantly.

- Companies with high turnover of employees, for example, tellers or sellers.
- Companies (including secondary and higher educational institutions) with geographically distributed branch networks. On one hand, the use of remote training products allows for providing the same training regardless of the branch location, and, on the other hand, it allows for saving a large amount of the company's money at the expense of travel costs for teachers and/or employees.

The analysis of the remote training organization experience at the Russian universities has shown that managements of many universities have developed and approved the models and road maps to introduce e-learning into the educational process, and allocated funds for material incentives for teachers. There has been developed and implemented a provision on implementation of e-learning. An additional monthly fee calculation method for teachers working with students through e-courses has been introduced. Parameters like technological course card formation, student e-course access, student e-course enrollment percentage, course grade book completeness, and percentage of students who took part in the education quality questionnaire served as additional monthly fees criteria.

The main difficulties in the e-learning introduction process are as follows:

- Solid belief among the education quality experts that the training efficacy depends solely on introduction of new electronic tools into the learning process.
- Lack of understanding among experienced teachers of what e-learning means. Many of them see e-learning as a dangerous competitor to the traditional learning model. Note that their worries are rather well founded in some cases (depending on the subject features).
- There are some teachers who clearly understand that, with the introduction of new

technologies, they will have to change their formal approach to teaching and authoritarian teacher–student communication style formed during the recent years and therefore resist the student feedback.

- A fairly large group of proactive and, as a rule, younger teachers has emerged who arrange their work with students by means of electronic courses which, however, cannot be considered satisfactory in many cases due to professional insufficiency.
- Low information culture level among employees.
- Poor knowledge of advanced methods and practices.
- Outdated employee motivation system.

For the purposes of legal registration and development impulse, the Russian Law “On Education” has been developed stating that e-learning should be considered an auxiliary tool for the traditional learning process.

Depending on the level of enhancing the learning process with the online content delivery technologies, the nature of interaction among participants and peculiarities of some subjects, the experts distinguish:

- Conventional training (without electronic technologies)
- Conventional web-supported training

The blended training system, which has been considered the highest quality and most promising learning process model worldwide (MIT Open Courseware 2014; Stanford Online 2014; Söderström et al. 2012), still constitutes a terra incognita for the Russian educational system. Russian experts believe that the blended training aimed at reduction of the number of classrooms due to transfer of a part of classes to the electronic environment will extremely impact the quality of professional training. In this sense, the flipped classroom technology is considered unacceptable since its essence is in the rearrangement of the key components of the educational process based on the active use of the electronic learning environment.

The traditional Russian web-based training system requires a teacher who will develop distance learning courses, electronic textbooks, training aids and assessment tools.

In this sense, a great role is played by the creative method of teaching, which, to a large extent, can influence the formation of students' attitudes toward science. Every teacher knows that the student's attitude to the subject, and, hence, to science, may be different. It may cause hate or disgust in some, dislike or indifference in others, or interest, love, and, finally, passion which may then develop into an obsession. In this case, the entire responsibility lies on a teacher almost exclusively, since, beyond any doubt, every subject studied by the listener is forever associated in his/her mind with a person who taught the subject.

However, a teacher, a lecturer, or an artist who is able to captivate listeners and evoke their interest with his/her topic from the other side of a screen is a rarity. We must admit that not many people are endowed with this gift.

There are many teachers who are fluent in the subject matter; they are wonderful researchers, but they absolutely lack any artistic ability. Many lecturers are too static and tense in front of a camera. They lack the freedom of communication that is usually there between the lecturer and the students in the classroom. A teacher who lectures from a monitor screen may be called a speaker in most cases.

Therefore, great attention is given to the quality of the basic element of distance learning – video lectures (Ardowsky 2006; Komarova 2006). The degree of professional preparation will determine the training success. Below are the recommendations for creating a high-quality video product.

Each lecture should be performed enthusiastically. If a teacher finds the lecture boring, then it is ten times more boring to the audience.

The lecture must be created like artwork. It must have a plot, plot development, and denouement despite the fact that the lecture cannot be considered a genuine artwork since it is only a part of the course, its piece. Nevertheless, the lecture must be created based on a certain emotional curve. Emotion is understandable: it is

the mood, which marks the whole lecture. To be more understandable during a lecture, as well as, for example, in a dramatic performance, a certain curve must always be present (e.g., Schiller's dramas are structured in a way that the central action, the maximum emotion is always present in the third act).

Since a lecturer enters the audience knowing his/her first word, he/she should know the last word before leaving the room. The end of the lecture should be thought over carefully just like the beginning.

Great attention should be paid to the direction of the lecture and its rehearsal. The direction of the form begins only after the thought-out content of the lecture, drawn-up emotions, developed drawings, selected examples. The first thing to do is find out what classroom and what blackboard you will use for your lecture. The direction of the text on the board is of great importance: you should know the board size to write the first line, if the board space is enough to provide some drawings, and so on.

A very important thing is the audience entrance plan: how would you enter it, if it is very large, for example?

It is necessary to think in advance about your posture and the words you will say. You should also know how to enter a specific lecture. This will largely determine its color, its tonality. The audience is a very accurate instrument that may reflect the lecturer's mood.

An important point is the direction of your gestures. It is necessary to think in advance whether you could help the audience understand your words using your gestures.

After the plan of directing all your gestures has been thoroughly thought out, it is necessary to think about your voice intonation, which is inextricably linked with the presentation. You should decide which intonation should be in which place of the lecture, where and how you could emphasize it. Intonation is very important since it can even give the audience some rest during the lecture.

Then a lecture rehearsal goes. First of all, a purely formal rehearsal is needed: it is necessary to check if everything you say can be quickly recalled.

After the rehearsal of the lecture contents, a rehearsal of all that has been intended should begin: your intonation, gestures, and so on. Then you need to put your watch on the table and repeat everything over again. This is especially important for the young teachers since they usually do not have a sense of time. The sense of time is one of the qualities that a lecturer needs.

A lecturer should give time to himself/herself and the audience to concentrate and create the necessary mood.

It is necessary to introduce elements of philosophy of a subject into the subject course, as well as historical, biographical information on the major persons into the presentation. Introduction of the elements of history into the training course should be performed in three directions:

- Paul Painlevé wrote, “It is necessary to give students an opportunity of touching the very roots of experimental methods and learn the most skillful techniques created by great researchers—skills and methods that are extremely subject-specific and much more convincing and fruitful than any theorem or rule” (Painlevé 1922).
- Extensive use of the richest historical material during the lectures. For example, the history of every general engineering science is very rich in examples emphasizing its importance to develop the military power of the countries and their equipment in general. Certainly, such examples can significantly increase the interest of students in the subject they study.
- Inclusion of biographies of the creators of certain sciences into the lecture. The pedagogical experience shows that a lively, vivid display of the leading figures in the world science like Galileo, Kepler, Lagrange, Coriolis, Bernoulli, and others helps not only reveal the methods and techniques of the scientific research to the students but also “breathe” that very scientific pathos into the audience, that very passionate attitude toward science which these great scientists were living with.

Summarizing the above, we can draw the following conclusions:

1. It is necessary to create high-quality multimedia applications for distant teachers so that these multimedia applications can be compiled taking into account the teacher’s rich past training experience.
2. A distant lecturer should undergo special artistic training whether it is an advanced training course or some acting technique classes.
3. An alliance between two professionals is also possible where one is a teacher and researcher and the other is a professional artist: the first one develops the course content and the second embodies the idea in front of the camera while both of them do one common thing.

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Artificial Intelligence in Education

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Synonyms

Adaptive learning; Augmented intelligence in education; Dialogue-based Tutoring systems; Intelligent tutoring systems; Personalised learning

Introduction

Artificial Intelligence (AI) technologies have been researched in educational contexts for more than 30 years (Woolf 1988; Cumming and McDougall 2000; du Boulay 2016). More recently, commercial AI products have also entered the classroom. However, while many assume that Artificial Intelligence in Education (AIED) means students taught by robot teachers, the reality is more prosaic yet still has the potential to be transformative (Holmes et al. 2019). This chapter introduces AIED, an approach that has so far received little mainstream attention, both as a set of technologies and as a field of inquiry. It discusses AIED's AI foundations, its use of models, its possible future, and the human context. It begins with some brief examples of AIED technologies.

The first example, *Cognitive Tutor*, is a type of AIED known as an *intelligent tutoring system* (ITS, which currently are the most common of AIED technologies). It addresses the domain of mathematics for students of primary or secondary school age, and aims to mirror a human tutor by delivering instruction personalized to each individual. *Cognitive Tutor* is also a rare case of an AIED technology that has bridged the gap from university research (at Carnegie Mellon University) to a successful commercial operation (Carnegie Learning (<http://www.carnegielearning.com>)) and is also unusual in having robust independent evidence of its effectiveness (Pane et al. 2014). As individual students work through carefully structured mathematics tasks, the system monitors the student's progress (successes and misconceptions), re-phrases questions, and re-directs the student along more suitable learning pathways and provides individualized feedback (explaining not just why the student got something wrong but also how they can get it right). It achieves all this by combining individual student interaction data with the interaction data of the many thousands of students who have already experienced the system, using that data to learn, adapt, and improve its models of mathematical skills and student learning.

A second quite different AIED example is *MASELTOV* (<http://www.open.ac.uk/iet/main/>

[research-innovation/research-projects/maseltov](http://www.open.ac.uk/iet/main/research-innovation/research-projects/maseltov)), a research project in which AI was used to support language learning by recent migrants to the UK, using devices that many people carry with them all the time – smartphones (Gaved et al. 2014). The *MASELTOV* smartphone app used GPS data and AI techniques to provide context-sensitive and personalized language-learning support. For example, the app was able to detect when a user entered a doctor's surgery or a supermarket, each of which would trigger it to recommend appropriate English resources personalized to the individual's language skills. In the supermarket, the app would provide vocabulary and phrases to help the user find the items that they wanted to buy; in the doctor's surgery, it would provide appropriate words (such as symptoms, parts of the body and diagnoses) together with information about the available health services.

A final brief example comes from China. *Smart Learning Partner*, from Beijing Normal University's Advanced Innovation Center for Future Education, is a mobile app that enables students to connect with tutors using their smartphones. Students can use the app at any time of the day or night to search for a tutor, in order to ask them specific questions about any school topic for which they want some additional support. There are several thousands of tutors available on the app, thanks to local government funding, all of whom have been rated (much like a shopping app or a dating app) by users (in this case, the users are other students). The student chooses their tutor (based on the school topic and the tutor ratings), connects and is given 30 min of free one-to-one online tuition (sharing voice and screens but not video). Although the AI is relatively simple, *Smart Learning Partner* uses it to provide a unique student-centered system that enables students to get exactly the support that they want (rather than the instruction that a system such as an ITS might prescribe). Data from all the interactions are then aggregated and made available to the schools, so that trends in student questions can in a virtuous circle be identified and given more attention in the classroom.

The AI Foundations of AIED

A full understanding of AIED depends on understanding something about AI more generally. The field of AI first emerged from a seminal workshop held at Dartmouth College in the USA as long ago as 1956. Over the following decades, AI developed in fits and starts with periods of rapid progress interspaced with periods, known as *AI winters*, where confidence and funding all but evaporated. Most recently, over the past decade, with the advent of faster computer processors, the availability of large amounts of big data, and the development of new computational approaches, AI has entered a period of renaissance.

Nonetheless, what actually constitutes AI still is often disputed (as is the name itself, with some researchers preferring *augmented* rather than *artificial* intelligence). In fact, for many, as has been suggested earlier, AI is synonymous with humanoid robots, which might be because AI and robots seem to feature together in the news and on television almost every day. In fact, while robotics is a core area of AI research, AI is being used in many different ways and is growing exponentially (while the dystopian images of futuristic robots remain firmly in the realm of science fiction). Paradoxically, though, the more that AI is integrated into our daily lives, the less we think of it as AI:

A lot of cutting edge AI has filtered into general applications, often without being called AI because once something becomes useful enough and common enough, it is not labeled AI anymore (Nick Bostrom, Director of the Future of Humanity Institute, University of Oxford) (<http://edition.cnn.com/2006/TECH/science/07/24/ai.bostrom/index.html>)

Instead, AI is often labeled as a computer program (such as email spam filtering), a mobile phone assistant (such as *Siri*), or perhaps an app (such as *Duolingo*). Nonetheless, many recent developments in AI have been both ground-breaking and transformative. AI techniques such as machine learning, neural networks, evolutionary computation, and supervised, unsupervised, and reinforcement learning have been used in applications as diverse as autonomous vehicles, online

shopping, auto-journalism, online dating, stocks and shares dealing, and legal and financial services.

Automatic face recognition, for example, is one area that has fairly recently made a dramatic leap forward while simultaneously becoming almost invisible in daily life (it is the technology used in smartphone cameras to ensure that faces are always in sharp focus and at e-passport gates to identify travelers before allowing them to enter a country). Face recognition was noticeably improved when, in 2012, Google presented a brain-inspired AI *neural network* comprising 16,000 computer processors with 10 million randomly selected YouTube video thumbnails. By using *deep-learning* techniques, and despite not being told how to recognize anything in particular, this *machine learning* system soon *learned* how to detect human faces in photographs. Two years later, Facebook introduced a nine-layer deep AI *neural network*, involving more than 120 million parameters, to identify (not just detect) faces in timeline photographs. It was trained on a dataset of four million images of faces that had previously been labeled by humans (Facebook users), and achieved an accuracy in excess of 97%, which almost matches human-level performance. However, although impressive, these examples also highlight a key difference between AI and human intelligence: a human does not need to see ten, or even four, million faces before it can recognize a family member, a friend, or a celebrity.

Another area that has seen much AI development is meteorological forecasting, with machine learning being shown to be more accurate at predicting weather than traditional simulation-based forecasting. Meteorologists have long tracked weather data which they enter into complex knowledge-based simulations to make forecasts. However, AI forecasting mines vast amounts of historical weather data, and uses *neural networks* and *deep learning* to identify data patterns (rather than to feed into simulations) in order to make data-based predictions about future weather conditions.

A final brief example is the use of AI in medical diagnosis, with AI techniques being used by radiologists to help them identify anomalies in

medical images more quickly and while making fewer mistakes. For example, one system looks for irregularities in X-ray images and, depending on what it finds, assigns it a priority. If it finds nodules on an image of a pair of lungs, it assigns a high-priority status and sends it to a pulmonary radiologist for further checks.

One thing that all these examples demonstrate is that AI is a highly technical area, which is too complex to explore in depth here (two seminal books that do cover much of AI's complexity are Russell and Norvig 2016; Domingos 2017). In fact, many people involved have advanced degrees in mathematics or physics, although AI is increasingly being offered as a "service" (for example, Google's TensorFlow, IBM's Watson and Microsoft's Azure). Nonetheless, because some have already been mentioned repeatedly and because they play an important role in AIED, some closely interlinked AI topics will be briefly introduced: algorithms, machine learning, deep learning, neural networks, and Bayesian networks. The section then concludes with a brief mention of so-called *General Artificial Intelligence*.

Algorithms

AI often involves talk of *algorithms*, which are simply descriptions of the steps needed to solve problems (ordinary computer programs are really nothing more than lengthy algorithms). It is probably fair to say that Google owes its existence to a single algorithm, PageRank (Fig. 1), which was developed in 1996 by the Google founders at Stanford University. PageRank (apparently named after the Google founder Larry Page rather than web pages) is an algorithm that ranked the relative importance of a website by counting the number and quality of external links to the website's pages, to determine where the website appeared in a Google search.

In fact, the history of AI might be thought of as the history of the development of increasingly sophisticated and increasingly efficient (or elegant) algorithms; while what makes AI algorithms distinct from other software is simply that they are applied to areas we might think of as essentially human (such as visual perception, speech recognition, decision-making, and learning).

Machine Learning

While most computer software (including much early AI) involves writing in advance the exact steps that the software will take, or specifying rules that will be followed exactly, machine learning is about getting computers to act without being given explicit steps or rules. Instead of the algorithms being *programmed* what to do, they have the ability to *learn* what to do. Image and speech recognition, self-driving cars, computational biology (for example, using computers to identify tumors), and digital companions (such as Amazon's Alexa), as well as the Google DeepMind AlphaGo program that beat the world's number one player of Go, have all been made possible thanks to machine learning. In fact, machine learning is so widespread today (almost everyone has experienced some form of machine learning usually without being aware of it) that for some researchers and developers it has become synonymous with AI.

There are three headline approaches to machine learning: supervised, unsupervised, and reinforcement. In **supervised learning**, the AI is first trained with data for which the output is already known. For example, the AI might be trained with many thousands of photographs of people that have already been labeled by humans (this is broadly speaking the approach, mentioned earlier, used by Facebook to *identify* people in photographs). The AI can then be used to label automatically new data (in this example, to

$$\text{PageRank of site} = \sum \frac{\text{PageRank of inbound link}}{\text{Number of links on that page}}$$

Artificial Intelligence in Education, Fig. 1 The PageRank algorithm that played a major role in the early years of Google

identify and label automatically the same Facebook users in new photographs). In **unsupervised learning**, on the other hand, the program is provided with even larger amounts of unlabeled data, which it uses to find patterns that enable it to classify new data (this is broadly the approach, mentioned earlier, used by Google to detect faces in photographs). Finally, in **reinforcement learning** the program is provided with some initial data from which it derives an outcome that is assessed as correct or incorrect, and rewarded accordingly (for example in an AI-driven computer game, the score is increased) or punished (the score is reduced). The program uses this to update itself and then it tries again, thus developing iteratively (evolving) over time.

Neural Networks

Machine learning often uses *neural networks*, so named because they are inspired by how neurons work and are connected in animal brains. However, although AI neural networks have been trained to do some incredible things, they are primitive in comparison to most higher-order animal brains. They usually involve only a few thousand *neurons* (in some exceptional cases, a few million) compared to the human brain, which has around 100 billion neurons and trillions of connections. In any case, AI neural networks comprise several layers of neurons (Fig. 2): typically an input layer (that takes stimuli from the environment), one or more hidden computational layers, and an output layer (that delivers the result of the computation). All the neurons are interconnected, with each connection having a

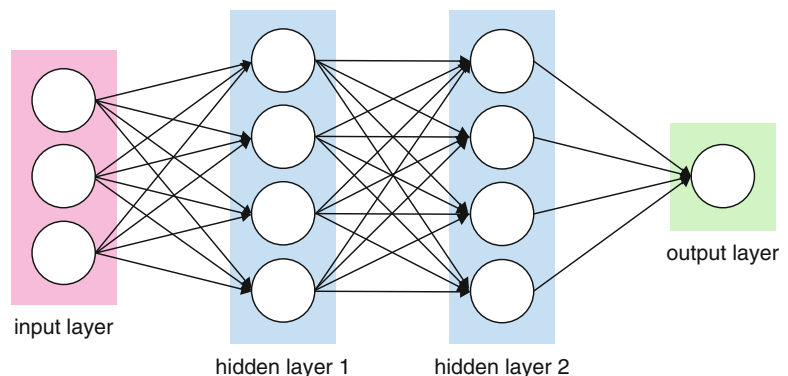
weighting to determine whether one neuron excites or inhibits the next neuron (again in a process inspired by synapses in animal brains). During the machine learning process, it is these weightings that are adjusted, usually by reinforcement learning, and that allow the AI subsequently to compute outputs for new stimuli. Neural networks have been shown to be particularly effective in many different AI systems, for example, for image recognition (identifying people) and natural language processing.

The hidden layers are key to the power of neural networks but they also bring an important problem. It is not possible (or at the very least it is not easy) to interrogate a neural network to find out how it came up with its solution (for example, how did it identify a particular person or a particular need?). In other words, neural networks can lead to decision-making for which the rationalization is hidden and unknowable, and possibly unjust (O'Neil 2017), a critical issue that is the subject of much research (e.g., Morcos et al. 2018).

Deep Learning

Neural networks comprising multiple hidden layers are known as *deep learning*. This involves automatic iterative analysis that clusters and classifies data and makes predictions. For example, once a deep learning algorithm determines that a picture contains a particular shape, it cycles again to find other shapes, and then cycles again to identify the connections between those shapes, iterating repeatedly until it has recognized what it is looking at (for example, a face). Deep

Artificial Intelligence in Education, Fig. 2 A representation of a typical simple neural network



learning is the headline approach used by *AlphaGo*, to learn how to win at the game of *Go*.

Bayesian Networks

Bayesian networks are a type of statistical model employed by some AI algorithms that enable, in uncertain domains, computational tasks such as prediction, anomaly detection and diagnostics. They combine principles from graph theory, probability theory, and statistics. Drawn graphically, a Bayes net comprises various lines (also known as edges) which intersect at nodes, with the nodes representing variables and the lines representing interdependencies between those variables.

To give a simple example, using a Bayes net approach, an AI system might be designed to predict (calculate the probability of) the flavor of ice-cream that a customer might buy depending on the weather and temperature of the day. Here, the nodes represent the known data (whether it is sunny, whether it is hot, and choices of ice cream flavor made by previous customers) and an uncertain outcome (what ice cream flavor will be chosen today). The Bayes net computation begins with probabilities given in each node that have been derived from training data (comprising records of weather, temperature and customers' choice of ice-cream flavors) to derive the probabilities of various outcomes (the ice-cream flavors that will be chosen by customers in a combination of weather and temperature circumstances). In fact, a typical AI Bayesian network might comprise tens (or hundreds) of variables (nodes) with intricate interdependencies (edges). However, the Bayesian computational approach makes it possible to infer precise probabilities in such complex environments in order to inform usable predictions (to continue with the example, to help the ice-cream seller decide how much of each ice-cream flavor to make).

General Artificial Intelligence

All the examples of AI mentioned so far are domain-specific, which means that they are tightly constrained and very limited. For example, the AI used to win at *Go* cannot play a game of chess, the AI used to predict the weather cannot predict

movements in the stock market, and the AI used to drive a car cannot be used to fly an aeroplane. So-called General Artificial Intelligence, AI that like human intelligence can be used in any circumstances, does not yet exist. And, despite the rapid developments in AI and the concerns expressed by many leading scientists (e.g., Hawkin et al. 2014), it is unlikely to exist for decades (even for leading AI advocates, General AI appears to be due to arrive at some ever-receding future date, usually around 30 years from the time of writing, Müller and Bostrom 2016). In fact, currently, rather than general applications (AI that can be used in any context, Domingos 2017), the focus for most AI research continues to be on domain-specific areas – such as autonomous vehicles, health, weather forecasting and stocks trading, and education.

Introducing AI in Education

AI in education research (AIED) has considered a variety of ways in which AI systems might be used to support both formal and informal learning. It has involved the development of many online tools that aim to support learning while being flexible, inclusive, personalized, engaging, and effective (Holmes et al. 2018). AIED brings together AI and the learning sciences, and thus involves two main complementary strands: developing AI-based tools to support learning and using these tools to help understand learning (how learning happens).

In addition to being the engine behind much “smart” ed tech, AIED is also a powerful tool to open up what is sometimes called the “black box of learning”, giving us deeper, and more fine-grained understandings of how learning actually happens. (Luckin et al. 2016, p. 18)

In other words, AIED research can have an important impact both on classroom tools (such as Cognitive Tutor) and on learning theories applicable in classrooms where there is no AI. For example, by modeling how students go about solving an arithmetic problem and, for example, identifying misconceptions that might have been previously unknown to educators, researchers and teachers can begin to understand much more about the

process of learning itself which can then be applied to classroom practices.

AIED Models

AIED often involves computational *models* (in AI, a model is a highly simplified computational representation of something in the real world, just like a model car is a simplified representation of a real car). In particular, *intelligent tutoring systems* (ITS such as Cognitive Tutor) are often built around three core models: *pedagogy*, *domain*, and *learner*, all of which interact in complex ways and are combined to adapt a sequence of learning activities for each individual student (Fig. 3). A fourth AIED model is the *open learner* model.

The AIED **pedagogy model** represents knowledge about effective teaching and learning approaches that have been elicited from teaching experts (and that constitute the learning sciences). This includes, for example, knowledge of instructional approaches (Bereiter and Scardamalia 1989), productive failure (Kapur 2008), guided discovery learning (Bruner 1961), collaborative learning (Dillenbourg 1999), the zone of proximal development (Vygotsky 1978), deliberate practice (Ericsson et al. 1993), interleaved practice (Rohrer and Taylor 2007), cognitive overload (Mayer and Moreno 2003), formative feedback (Shute 2008), uncertain rewards (Fiorillo 2003), and assessment for learning (Black et al. 2003).

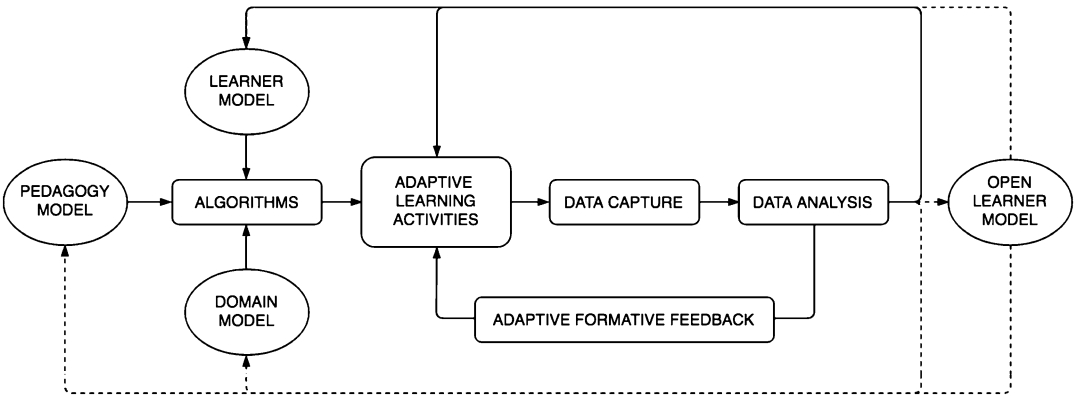
The AIED **domain model**, on the other hand, represents knowledge about the subject that the system aims to help the students learn. This might, for example, be knowledge about mathematical procedures, genetic inheritance, or the causes of World War I. In fact, over the years, mathematics for primary and secondary school students has dominated AIED (mathematics, along with physics and computer science, are AIED's low-hanging fruits because they are, at least at school and undergraduate level, well-structured and clearly delineated), although recent AIED research has investigated AI to support learning in less well-defined areas (such as essay writing across the humanities, Landauer et al. 2009; Whitelock et al. 2015). Finally, the AIED **learner model** represents knowledge about the students (for example, about student interactions, achievements, challenges, misconceptions,

responses, and emotional states while using the system), both for all the students who have used the system so far and for the individual student using the system right now. Figure 3 shows how these three models might be connected in a typical AIED intelligent tutoring system.

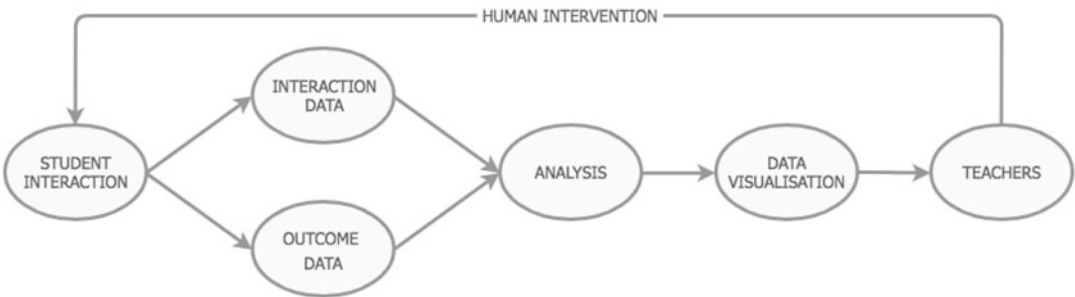
In this exemplar architecture, algorithms draw on the pedagogy, domain, and learner models to determine what specific learning activity (for example, some textual content or a collaborative learning activity) should be presented to the individual student and how it should be adapted to that student's needs and capabilities (over time, this means that individual students experience their own unique personalized learning pathways). Then, while the student engages with this adaptive learning activity, the system automatically captures thousands of data points representing each individual interaction, the student's achievements, and any misconceptions that they have demonstrated. Some systems also capture other data such as the student's speech and an indication of their affective (emotional) state.

All of this data is then analyzed (possibly using machine learning or Bayesian network techniques), both to provide the student with individualized formative feedback (to support their learning according to their individual needs) and to update the learner model (to inform the system's next adaptive learning experience). The analysis might also, in some circumstances, update the pedagogy model (with those approaches to pedagogy used by the system that have been shown to support student learning most effectively) and domain models (perhaps with previously unknown but apparently not uncommon misconceptions).

Some AIED ITS also feature a fourth model, the open learner model shown in Fig. 3 (Dimitrova et al. 2007). Open learner models aim to make visible (explicit), for the learners and teachers to inspect, both the teaching and learning that has taken place and the decisions that have been taken by the system (which is especially important if the system uses a neural network approach where, as noted earlier, it can be otherwise difficult to decipher how a decision has been made). This enables learners to monitor their achievements and



Artificial Intelligence in Education, Fig. 3 Flowchart representing a typical AIED intelligent tutoring system architecture, including the pedagogy, domain, learner and open learner models



Artificial Intelligence in Education, Fig. 4 A simplified overview of learning analytics

personal challenges, supporting their metacognition, and enables teachers to better understand each individual learner’s learning (their approach, any misconceptions, and their learning trajectories) in the context of the whole class.

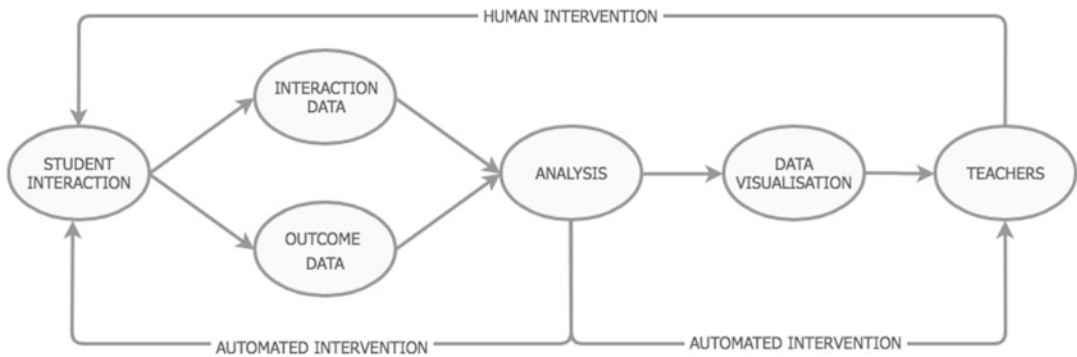
AIED and Learning Analytics

AIED is sometimes linked to another developing field of research in education known as Learning Analytics (LA) or Educational Data Mining (EDM). LA, to focus on just one, involves “the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs” (Siemens 2011). It applies statistical techniques from big data research (Mayer-Schonberger and Cukier 2013) to digital traces in educational contexts. In many ways, there are clear overlaps

between LA and AIED (Figs. 4 and 5). In both LA and AIED, student interaction and outcomes data are analyzed, and the results may be shown in visualizations (for example, in student dashboards). However, although the distinction is becoming increasingly blurred, while LA typically uses the data and analysis to provide insights to inform human intervention (by, for example, teachers), AIED uses the data and analysis to initiate some kind of automatic intervention (such as personalized feedback or learning pathways for students, or automatic student forum post aggregation for teachers).

AIED Applications

There are many AIED-driven applications being used in schools and universities. Here, building on



Artificial Intelligence in Education, Fig. 5 A simplified overview of AIED

the examples mentioned earlier, an illustrative sample is surveyed. As mentioned earlier, the most common types of AIED are so-called *intelligent tutoring systems* (ITS), with Cognitive Tutor being a leading example (for a comprehensive history and discussion of ITS see Woolf 2008). ITS aim to simulate one-to-one (personal) human tutoring, which has long been thought to be the optimum condition for learning, although it is typically costly (at least in terms of teacher time) and so beyond the reach of most students. Famously, Benjamin Bloom (1984) calculated that students receiving personal tuition could achieve outcomes that were two standard deviations (2-sigma) above students taught in conventional classrooms. Although the accuracy of this has recently been challenged (VanLehn 2011), the aim of many ITS researchers has been to devise systems that answer the “‘2-sigma problem’. Can researchers and teachers devise teaching-learning conditions that will enable the majority of students . . . to attain levels of achievement that can at present be reached only under good tutoring conditions?” (Bloom 1984). In fact, VanLehn calculates that the correct figure for human tutoring is closer to 0.8 sigma and that many ITS are already almost as effective (VanLehn 2011).

Three influential examples of personal tutors are *AutoTutor*, *Andes*, and *CIRCSIM*, each of which has been shown to achieve at least 1.0 sigma improvement over conventional classroom teaching. *AutoTutor* was an online system that aimed to “simulate the dialogue patterns of

typical human tutors” in the domain of computing (Graesser et al. 2001). The system’s pedagogy model adopted the principle that it is important “to encourage students to articulate lengthier answers that exhibit deep reasoning rather than deliver short snippets of shallow knowledge” (ibid.), which it addressed by engaging students in a series of written exchanges and by prompting them to elaborate. Meanwhile, feedback mechanisms included providing hints, extending student responses, and correcting misunderstandings. *Andes*, on the other hand, was an ITS focusing on the domain of physics that aimed to replace students’ pencil and paper homework with an interactive and intelligent interface. The system presented students with physics problems for them to solve, each of which usually consisted of many steps (such as drawing vectors, drawing coordinate systems, defining variables and writing equations). After the student completed each step, the system gave feedback, such as hints on what was wrong with an incorrect step or what kind of step to try next. Finally, *CIRCSIM* was a language-based ITS for 1st-year medical students, which was designed to help them learn about the reflex control of blood pressure. It involved one-to-one interactions between the student and the computer, using natural language processing and generation, adopting a pedagogy model that assumes “real understanding of something involves, at least in part, an ability to describe the basic concepts in appropriate language” (Evens and Michael 2006). Accordingly, students were asked to

solve small problems while engaging (similarly to *AutoTutor*) in a Socratic dialog (an iterative conversation of questions and responses) with the computer.

An example alternative to ITS is *iTalk2Learn*, an AIED system for children aged 8–12 years old who are learning fractions, which was designed to detect, analyze and respond to speech in real time in order to improve learning (Rummel et al. 2016). Specifically, the platform supported the robust learning of fractions by providing activities to help develop both *conceptual* and *procedural* knowledge of fractions. Conceptual knowledge is fostered in an exploratory learning environment called *Fractions Lab*, which facilitates students to answer given fractions tasks using virtual manipulatives (graphical representations of fractions) in any way that they choose. Procedural knowledge, on the other hand, is fostered by structured practice activities, in a commercial ITS called *Maths Whizz*. A student's unique sequence of interleaved exploratory and structured practice activities is determined by an overarching intervention model (Mazziotti et al. 2015), the aim being to achieve optimum conditions for learning (avoiding students being under- or over-challenged, which may trigger either boredom or anxiety). Sequencing decisions are made according to the student's level of *challenge* and their *affective state*, both of which are inferred from the student's interaction (what they click and the actions they take on the screen) and their speech (including key words and prosodic features such as “um's” and pauses) and all of which are recorded in the student model. Throughout, the system uses a Bayesian network approach to deliver targeted formative feedback at three levels: *Socratic*, *guidance*, and *didactic* (Holmes et al. 2015). *Socratic* feedback draws on the dialogic approach to teaching (Alexander 2010), which emphasizes the benefits of open questioning to encourage students to consider and verbalize possible solutions. The second level, *guidance*, reminds students of key domain-specific rules and the system's affordances. The third level, *didactic* specifies the next step that needs to be undertaken in order to move forward (this rarely-delivered final feedback also operates as a back-stop, ensuring that the student is not left floundering).

Another example AIED is *OpenEssayist* (Whitelock et al. 2013), which uses Natural Language Processing to provide automated meaningful feedback on draft essays. Unlike earlier AIED systems that were developed to *grade* essays and to *instruct* students how to fix problems (such as Criterion, Burstein and Marcu 2003; Summary Street, Franzke and Streeter 2006; and IntelliMetric, Rudner et al. 2006), *OpenEssayist* encourages the user to reflect on the content of their essay in order to promote self-regulated learning, self-knowledge, and metacognition. It uses linguistic technologies, graphics, animations, and interactive exercises to enable users to reflect on whether the essay adequately conveys the intended meaning and to self-correct before submitting their essay for summative assessment. The system was based on the assumption that the quality and position of key phrases in an essay illustrate how complete and well-structured the essay is, which it determined by means of key phrase extraction, identifying which short phrases are the most suggestive of an essay's content, and extract summarization.

Another use of AI in education is to focus on supporting teachers to support students, rather than on supporting the students directly. One example of this is the *Virtual Teaching Assistant* known as *Jill Watson* (JW), developed at Georgia Tech to address difficulties in providing automatic online assistance for large cohorts of students, particularly in online courses (Goel and Polepeddi 2017). JW was designed to monitor the online forum of a computer science course, to recognize common questions raised by the students, and to provide answers both accurately and quickly. Rather than replacing the human teaching assistants, JW aimed to relieve them of having to respond to low-level questions (such as enquiries about length of assignments, dates for submission, and required readings), which can be both time-consuming and tedious, to allow them to focus on higher-level and thus typically more interesting questions and other teaching activities. JW was originally developed using the IBM Watson AI as a service platform and broadly adopted a supervised learning approach. It was trained with two connected datasets developed over three semesters: the questions that students had asked,

mapped to (labeled with) the answers that the human teaching assistants had provided. Thus trained, the system evaluates new student questions to determine if they can be mapped to question/answer dyads for which the system has confidence (because similar questions have been posed and answered many times). The appropriate answer is then selected and immediately returned to the student. On the other hand, if an appropriate answer cannot be identified with confidence, the question is referred up to a human teaching assistant without introducing any noticeable delay.

Finally, some brief examples involving AIED and two quite different learning approaches: collaborative learning and virtual reality. Research (e.g., Dillenbourg 1999) has shown that collaborative learning, which might involve two or more students undertaking a project together, can be more effective than learning alone. Collaborative learning can, for example, encourage students to articulate their thinking, to resolve differences through constructive dialogue, and to build shared knowledge. However, other research (e.g., Slavin 2010) suggests that collaboration between learners rarely happens without appropriate support. For this reason, various approaches using AI to support collaborative learning have been researched.

AI-driven adaptive group formation, for example, uses knowledge about the participants, most often in learner models, and self-learning algorithms to form a group best suited to a particular collaborative task (perhaps students are all at a similar cognitive level and have similar interests, or they bring different but complementary knowledge and skills) (Mujkanovic et al. 2012). Meanwhile, expert facilitation can involve training systems to support students collaboratively sharing knowledge. For example, Soller et al. (2002) developed a system using Hidden Markov Modeling (another probabilistic technique used in AI) to identify effective and ineffective knowledge sharing between students, so that intelligent guidance might be provided to foster more productive knowledge exchange (while blockchain technologies might enable the fair attribution of credit for individual contributions, Mathews et al. 2017).

Finally, intelligent virtual agents might mediate online student interaction, or simply contribute to the dialogues by acting as a coach, a virtual peer, or a teachable agent (i.e., a virtual peer that the participants might themselves teach). For example, Goodman et al. (2005) developed an agent that interacted with the participants when it detected something happening that was interfering with the learning (such as a student's confusion about a problem or a participant who is dominating the discussion or not interacting productively with other participants).

Virtual reality (VR) and augmented reality (AR) enhanced with AI are both being promoted as having potential for learning. VR can provide authentic experiences that, using VR headsets, headphones, and controllers, simulate in immersive 4D (the three dimensions of space plus sound or haptics) a small part of the real world to which the user would not otherwise have access. These include places such as dangerous environments (like the interior of a volcano) or somewhere geographically or historically inaccessible (such as a black hole or the Cretaceous Period). However, while some (e.g., Hassani et al. 2013) have suggested that learning in virtual realities can enable the student to better transfer that learning to the real world (transfer of learning has long been known to be a problem), and there are examples of VR being used to support medical training (e.g., Ruthenbeck and Reynolds 2015), in a review of VR in K-12 education, Freina and Ott (2015) were unable to find any robust learning outcomes.

Augmented Reality adopts a different approach. Instead of providing an alternative reality, AR overlays rich media (virtual objects such as text, still images, video clips, 3D models, and animations) onto live video images of the existing reality, by means of the cameras and screens on smartphones and tablet devices, in such a way that users perceive the virtual objects as if they are coexisting with the real-world environment. There are many examples. AR techniques can be used to show textual information about a specific mountain (such as its name and maximum elevation) when a smartphone's camera is pointed at it (<https://www.peakfinder.org/mobile>); while another AR app has been

developed, for use in a university science course, that allows the user to view and interact with an anatomically correct 3D model of a human heart. (<https://appstore.open.ac.uk/humanheart>) Nevertheless, despite the promise, again there is currently little evidence that AR leads to any notable learning gains (Bower et al. 2014; Radu 2014).

The Future of AIED

As is clear from both media and this brief review, AI and AIED are rapidly developing areas of research and development. In particular, AIED applications that yesterday seemed fanciful, today are being widely used by students, independently or in schools and universities. Future possibilities are limited only by the imagination and are thus difficult to predict. Here, therefore, briefly surveying four areas in which AIED has substantial potential (building on Luckin et al. 2016) will have to suffice.

Twenty-First-Century Skills

What have been called *twenty-first-century skills* have repeatedly been identified as essential for future students, future work, and future economies (e.g., World Economic Forum and The Boston Consulting Group 2016). These skills include competencies such as critical thinking, problem-solving, creativity, communication, and collaboration, together with character qualities such as curiosity, persistence, adaptability, leadership, social and cultural awareness, and initiative. However, although these essential skills and character qualities may be important, it is unclear how they might best be developed or supported.

AIED might help enhance students' twenty-first-century skills by providing dynamic tools that iteratively improve. For example, while students engage in collaborative problem solving activities in a particular context, the tools might monitor student actions (Who is interacting with the available learning resources and how?), eye contact (What are learners focusing on at any particular time?) and dialogue between groups of students (Who is saying what and to whom?). Over time, it will be possible to identify indicators of the most effective collaborative problem solving strategies, so that students might be guided

(perhaps through automated feedback) in those directions. Monitoring and analyzing dialogue might also be used to connect students engaged in similar conversations, either on opposite sides of the room or in different countries, helping to build AIED-supported communities of practice. Meanwhile, the impact of the context may be further accommodated by means of an additional model built into the AIED system, which might help identify how the combinations of technology, teachers, and environment might be adjusted to improve teaching (Luckin 2010).

Twenty-First-Century Assessment

AIED technologies also have the potential to replace the *stop and test* approach to assessment, as exemplified in examinations. It is well-known that teaching-to-the-test, an inevitable consequence of examinations, impoverishes learning. In any case, exams (for which there is little evidence of efficacy or validity) can only assess a fraction of what has been learned and so provide only a partial picture of a student's capabilities. Exams can also be the cause of serious anxiety for many students.

AIED techniques could, on the other hand, provide continuous formative assessment and just-in-time feedback about learner successes, challenges, and needs that can then be used to shape the learning experience itself (c.f., Foltz 2014). For example, AIED could monitor changes in learner confidence and motivation as they achieve competencies in a new language or in a new topic in geography or history. Alternatively, AIED-driven *stealth* assessments (Shute 2011) could be built into meaningful learning activities, for example, in digital games-based learning or collaborative projects. This might involve continuously monitoring the various indicators of learning, accrediting, and recording the learning as it happens (perhaps in blockchain-secured robust e-portfolios, Sharples and Domingue 2016), and automatically providing guidance on appropriate next learning steps.

Twenty-First-Century Learning Partners

Finally, AIED also has the potential to build artificial *learning companions* that might accompany

and support individual learners throughout their lives. These lifelong learning companions could be accessible via speech on smartphones (and on other smart devices such as Alexa, Siri, or Google Home), and could provide an easy-to-access record of a student's individual learning experiences, successes, and challenges, together with suggestions and ongoing guidance for future study. They might also connect just-in-time with other specialist AIED systems, or with humans who have expertise in particular subject areas (building on the approach used by the *Smart Learning Partner* from Beijing mentioned earlier). Inevitably, at first there will be objections, that learning companions discourage the students from learning the classroom knowledge that has traditionally been deemed to be important. However, in time, as the learning companions enable and support students to make novel connections between learning objects and learning domains that otherwise would have been difficult if not impossible, helping them to build upon and enhance their learning wherever it happens, and as the learning companions become commonplace, perhaps their value will eventually be accepted (in much the same way that calculators are finally becoming accepted in classrooms, Hodgen et al. 2018). Similar AIED could also be used to develop AI teaching assistants, designed to support teachers in their day-to-day work, removing some of the drudgery of teaching and allowing them to focus on the more human aspects of learning.

The Ethics of AIED

No discussion of AI in education can be complete without some consideration of the ethical implications. Yet, while the range of AI technologies being introduced in schools and universities around the world are extensive and growing, the ethics are rarely investigated. There has been work around the ethics of AI in general (e.g., Bostrom and Yudkowsky 2014) and around the ethics of Learning Analytics (e.g., Slade and Prinsloo 2013). However, at the time of writing,

around the world, virtually no research has been undertaken, no guidelines have been provided, no policies have been developed, and no regulations have been enacted to address the specific ethical issues raised by AIED. In short, researchers and developers in AIED are proceeding without any fully worked out ethical groundings, such that it might be argued that all AIED technologies, including those that have been introduced in this chapter, exist in a moral vacuum.

In fact, although perhaps not as newsworthy as robots or self-driving cars, the use of artificial intelligence techniques (such as neural networks, machine learning and Bayes nets) in education has profound implications for students (their skills, knowledge and developing minds) and thus for wider society. In parallel, this also raises an indeterminate number of as yet unanswered ethical questions. To begin with, concerns exist about the large volumes of data collected to support AIED (such as the recording of student competencies, emotions, strategies, and misconceptions). Who owns and who is able to access this data; what are the privacy concerns; how should the data be analyzed, interpreted, and shared; and who should be considered responsible if something goes wrong? For these questions, AIED might usefully draw on the work that investigates the ethics of Learning Analytics (e.g., Slade and Prinsloo 2013). However, while data raises major ethical concerns for the field of AIED, AIED ethics cannot be reduced to questions about data. Other major ethical concerns include the potential for bias (conscious or unconscious) incorporated into AIED algorithms and impacting negatively on the civil rights of individual students (in terms of gender, age, race, social status, income inequality. . .). For these questions, AIED might usefully draw on the work that investigates the ethics of AI in general (e.g., Caliskan et al. 2017). But the AIED ethical concerns centered on data and bias are the “known unknowns.” What about the “unknown unknowns,” the ethical issues raised by and specific to the field of AIED that have yet to be even identified?

One approach is to consider ethical issues in terms of the three main AIED models introduced earlier. At the pedagogical level, the impact of

AIED on pedagogical relationships and how best they can be supported first needs to be addressed. For example, what kinds of AIED interventions are ethically warranted, what kinds of information should be used to justify an AIED intervention, and what kinds of behavioral changes is AIED intended to bring about? At the domain level, it is important to consider how the adaptation of particular subject content amenable to AIED influences the learner experience and their understanding of that content. Finally, at the level of individual learners, issues center on the use of personal information. In addition to the use of learning analytics to profile learners, these include issues around surveillance and covert data collection (involving cutting edge technologies that are poised to collect ever more personal information), and the tension between paternalistic systems and the autonomy of the learner.

Specific AIED ethical questions include: What are the criteria for ethically acceptable AIED? How does the transient nature of student goals, interests, and emotions impact on the ethics of AIED? What are the AIED ethical obligations of private organizations (developers of AIED products) and public authorities (schools and universities involved in AIED research)? How might schools, students, and teachers opt out from, or challenge, how they are represented in large datasets? And, what are the ethical implications of not being able to easily interrogate how AIED deep decisions (using multi-level neural networks) are made?

Strategies are also needed for risk amelioration, since AI algorithms are vulnerable to hacking and manipulation. Where AIED interventions target behavioral change (such as by “nudging” individuals towards a particular course of action), the entire sequence of AIED enhanced pedagogical activity also needs to be ethically warranted. And finally, it is important to recognize another perspective on AIED ethical questions: in each instance, the ethical cost of *inaction* and *failure to innovate* must be balanced against the potential for AIED innovation to result in real benefits for learners, educators, and educational institutions.

Cross-References

- ▶ [Augmented Reality in Education, Scope of Use and Potential](#)
- ▶ [Computer-Assisted Instruction, Changes in Educational Practice as a Result of Adoption of ICT](#)
- ▶ [Computer-Assisted Learning](#)
- ▶ [Computer-Based Training and School ICT Adoption, A Sociocultural Perspective](#)
- ▶ [Educational Assessment, Educational Data Mining, and Learning Analytics](#)
- ▶ [Robotics in Education](#)
- ▶ [Technology Enhanced Learning](#)

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Assessment

► Competency Models in Computing Education

Assisting Elderly Non-computer-Literate People with Computer-Based Communications

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Synonyms

Access; Active aging; Computer-based communications; Health information; Internet

Introduction

Aging is emerging as an issue since both the proportion and absolute number of older people in populations around the world are dramatically increasing (WHO 2015). With advances in medicine helping more people to live longer lives, the number of people over the age of 60 years is expected to double by 2050; global life

expectancy has increased by 5 years since 2000 (Gulland 2016) and is expected to increase in industrialized countries. With societies aiming to provide an active aging context for the elderly, a fourth age challenge is emerging. In this context, in addition to the importance of considering the views and needs of the eldest, it is also pertinent that their continuous participation in social, economic, cultural, and spiritual dimension opportunities, together with the promotion of healthy physical development, is ensured.

Assisting elderly non-computer-literate people with, and in the familiar/friendly use of, computer-based communications and Internet access answers a challenge of today's society. Through collaboration between aging and active people and bearing in mind the potential of information and communication technology, it is possible to ensure basic rights to well-being, thus contributing to a better culture of old age (Baltes and Smith 2003). This acknowledges older people's continuing aspirations to well-being and respect (WHO 2015). In a context of progressive Internet societal omnipresence, many believe that if offline older citizens remain offline, they will become increasingly disadvantaged from a socio-ecological point of view. Encouraging older adults' use of information and communication technologies (ICTs) is essential for the creation of bona fide information societies (Selwyn et al. 2003).

Computer-Mediated Communication and Digital Technology Development

With the digital revolution, in the digital era, all entities, collectively or individually considered, are connected to each other, anytime and anywhere, through ubiquitous and pervasive computing. Wireless and mobile technologies, sensing devices, and virtual and augmented reality applications are examples of available technology that has an impact in societies and in the lives of everyone. The complementarity of the Internet of Things, consisting of intelligent and self-configuring nodes interconnected in a dynamic and global network infrastructure, and of cloud computing, which makes real virtually limitless

storage and on-demand processing power (Botta et al. 2016), enables a varied and large number of application scenarios.

Nowadays, computer-mediated communication and digital technologies are increasingly ubiquitous, easily available, and, most of them, user-friendly. Being able to use a digital tool or an application is being facilitated by a number of institutions and structures in societies, via international, regional, and national programs, sometimes through social and educational activities where, despite any initial negative attitudes, success in training is more a function of a proper training program than participants' attitudes (Mitzner et al. 2016).

Adoption and Use of Computer-Mediated Communication by the Elderly

Elderly people are users of computer-mediated communication for a variety of purposes, such as seeking general information, accessing health documentation, and managing health issues, shopping, banking, or online learning. Further to these kinds of pragmatic uses, computer-mediated communication and the Internet may have a role in reducing social isolation and in promoting interconnectedness and social stimulation; information and communication technology, in general, may offer intelligent and supportive living environments that support older people's cognitive and physical problems (Nugent 2007). Despite concerns that some of these technologies also have the potential to restrict freedom of movement and intrude into privacy (Bennett et al. 2017), research also shows that Internet usage by healthy older adults is a safe activity (Karin and Martin 2013). Published research clearly shows evidence that technology, in general, and more specifically computer-mediated communication, can play a relevant role in assisting the elderly: (i) if introduced with foresight and careful guidelines, robots and robotic technology can improve the lives of the elderly, reducing their dependence and creating more opportunities for social interaction (Sharkey and Sharkey 2012); (ii) information and communications technologies

may, to some extent, play an instrumental role in interconnectedness and social stimulation, between the elderly and their families (Bobillier Chaumon et al. 2014); and (iii) in long-term care institutions, the Internet may become an important window to the community (Seifert et al. 2017).

Research and Policy

Research through a systematic review by Peek et al. (2014) shows that technology that enhances safety or provides social interaction is influenced by multiple factors; its authors called for further research to determine if and how the factors are interrelated and how they relate to existing models of technology acceptance. Knowing and understanding how to assist non-computer-literate elderly with computer-based communications is an established field of research, where it has been noted that higher levels of Internet use may be significant predictors of higher levels of social support, reduced loneliness, and better life satisfaction and psychological well-being among older adults (Heo et al. 2015). However, the impact of the Internet on the well-being of the elderly may well be complex (Mellor et al. 2008) and requires continuous research. As stated by Wagner et al. (2010), computer use by older adults is a multidisciplinary topic by nature, requiring research through different methodologies, operationalizations, constructs, or relationships from different disciplines.

In addition to research, the wider community should ensure adequate policy that provides the non-computer-literate elderly with proper state-of-the-art assistive technology and personalized and knowledgeable assistance. Programs and initiatives that may take place can be illustrated by case studies already conducted and published: (i) Patrício and Osório (2016) showed that intergenerational learning with information and communication technology (ICT) contributes to the digital literacy of adults and seniors and fosters lifelong learning, active aging, and understanding and solidarity among generations; (ii) Horwitz and Huss (2016) studied online cultural products as a mediating element for communication between youth and elders; (iii) Brites-Pereira

et al. (2017) are studying how the elderly learn to use digital technologies of movement detection, in a context of developing active aging.

In addition to challenging strategies, such as intergenerational learning, and rich cultural content stimuli, programs and policies need to comply with a multitude of conditions (Larsson et al. 2013), and providers may ponder the enjoyment benefit of the Internet (Lee et al. 2014). Furthermore, for digital seniors, ICT use is not a binary choice because they want to have the flexibility to select for themselves under what circumstances and for what purposes the use of ICTs is appropriate (Quan-Haase et al. 2016).

Listening to the voices of people who have learnt through a whole life will certainly be helpful to assist the elderly not only in computer-mediated communication literacy but also in the adoption of a lifelong learning paradigm.

In summary, a fourth age is emerging, in which assisting the elderly in the use of computer-based communications answers a challenge of today's society. Nowadays, computer-mediated communication and digital technologies are increasingly ubiquitous, easily available, and (for the most of them) user-friendly; in addition, research shows that technology can play a relevant role in assisting the elderly. Therefore, assisting the elderly in using computer-mediated communications not only provides the discovery of new knowledge but also contributes to an active meaningful and dignified aging.

Cross-References

- [Assistive Technology and Inclusion, Philosophical Foundation](#)
- [Lifelong Learning for Working People](#)
- [Literacy and technology](#)
- [Policy Rationales and Integration Rationales, Implications for Subject Area Teaching](#)

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Assisting People Who Are Deaf or Hard of Hearing Through Technology

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Synonyms

Alerting devices; Assistive listening devices; Captions; Deaf; Hard of hearing; Text messaging; Video streaming

Introduction

Technologies assist individuals who are deaf or hard of hearing (DHH) with access to spoken

information in classrooms, at work, and in primarily social situations; technologies also help individuals who are DHH share information with hearing individuals. These technologies make it possible for individuals who are DHH to participate effectively in activities, when it would not otherwise be possible, such as by providing captions so that individuals who are DHH can follow television programs. Some of these technologies provide information visually, and others enhance auditory information (Gallaudet 2014). Technologies that assist individuals who are DHH may have a feature, such as captions, which is specially designed for them, or may be intended for a wide range of individuals and also meet the needs of individuals who are DHH in certain situations such as the use of networked messaging to facilitate communication between individuals who are DHH and individuals who are hearing (Gray 2008; Gray et al. 2011).

This entry will consider the following five types of technologies that facilitate communication, learning, and participation of DHH individuals:

1. Assistive listening devices (ALDs) that facilitate the access of individuals who are DHH to auditory signals by improving the loudness or clarity of the signal.
2. Captioning technologies that provide individuals who are DHH access to spoken information in classrooms, to television programs and web material, and to phone conversations.
3. Text messaging technologies that enable synchronous (simultaneous) and asynchronous (nonsimultaneous) text communication between individuals who are DHH and individuals who are hearing, often in situations where an interpreter is not available to facilitate communication.
4. Video streaming technologies that make possible remote conversations between individuals who use a sign language.
5. Alarm and alerting devices that help individuals who are DHH with numerous functions in everyday life, such as answering the doorbell; these technologies also operate as signal alerts, such as for catastrophic weather.

Factors that Affect Use of Technology

Before considering these five sets of technologies, the following discussion briefly summarizes three issues that have implications for the nature and effectiveness of technology used with individuals who are DHH: (a) education and work settings, (b) language and academic skills of DHH individuals, and (c) trends in technology.

Educational and Work Settings

With respect to education, virtually all students who are DHH are educated in two types of classrooms, special and general education (mainstream). Special classes typically have a teacher of the deaf, and communication tends to be in a sign language. Communication is more accessible to students who are DHH because if they are in that setting, the teacher regulates the flow of communication and adjusts to the children's communication needs so that the students can understand (Stinson and Kluwin 2011). General education classes are those with primarily hearing students and a regular teacher. Typically, only one student who is DHH (or only a few) is placed into any particular general education class. In these classes, the teacher and students almost always use a spoken language (e.g., English, Greek), and the students who are DHH in these classes usually have difficulty understanding at least some of this communication, unless they receive special services to support communication access and learning. A somewhat similar type of distinction occurs when individuals who are DHH enter the work world. These individuals may work in positions with primarily hearing co-employees, and thus there is often a need for technology that can help individuals who are DHH have access to the spoken communication of hearing employees. A good, but relatively small, number of employees who are DHH work in settings where most employees know a sign language (such as in a school for the deaf), and for them much communication with fellow employees is through a sign language (Kelly et al. 2016).

Communication Characteristics

Two characteristics of individuals who are DHH that affect learning and employment are limited proficiency in reading and writing (Qi and Mitchell 2012; Nikolarazi et al. 2013) and considerable diversity in communication characteristics (Knoors and Hermans 2010). Students who are DHH vary in the knowledge, understanding and use of a sign or a spoken language, and proficiency in reading and writing. These variations relate to the extent that students are placed in general education or special education classes, as well as the nature of accommodations that a student may request, including provision of a sign language interpreter or real-time captioning (Knoors and Hermans 2010; Stinson and Kluwin 2011).

Five Assistive Technologies

Assistive Listening Devices

Language development in a spoken language among individuals who are DHH is associated with the use of the proper listening devices and the benefit that this device provides (Ambrose et al. 2014). In addition to the personal listening device, either hearing aids or cochlear implant, assistive listening devices can improve the quality, audibility, and clarity of the speech signal. In many listening environments, the signal-to-noise ratio (SNR) is very low, that is, that the level of signal (i.e., teacher) is lower than the level of the background noise. This prevents speech perception for an individual, particularly a child, with functional hearing, who needs the signal to be louder than the background noise. The use of assistive listening devices (ALDs) can facilitate the detection of the sound and improve SNR by minimizing background noise, the distance between the sound source and listener, and reverberation (Hinman et al. 2003; Kim and Kim 2014; Dillon 2012; Zanin and Rance 2016).

The most common assistive listening devices include the soundfield amplification systems, the frequency modulated (FM) radio systems, the infrared (IR) transmission, and the magnetic

induction loop. The soundfield systems include a wireless microphone and wireless receiver/amplifier that powers loudspeakers that are placed around the classroom, often on the walls. These speakers are linked to a control center, which can transmit sound from various devices – for example, a microphone worn by a person speaking, a music system, or a whiteboard. The portable systems can be moved around to wherever they are most needed. In rooms with poor acoustics, soundfield systems might be of less benefit because they increase the loudness of the speech signal as well as reverberation. Therefore, the ideal is to use a soundfield system in a classroom with good acoustics. Also, a pass-around microphone is often important because it can amplify the voice of other speakers (i.e., classmates) who might make comments and ask questions (Aussie Deaf Kids 2015; Dillon 2012; Hinman et al. 2003; Inglehart 2002; NDCS 2017; Zanin and Rance 2016).

Additional ALDs include the FM and the IR systems which are both wireless systems that consist of two units, a portable receiver for the listener and a microphone transmitter for the speaker. FM systems use radio waves, while IR systems use light waves. Radio waves travel through the walls, and therefore FM systems in nearby rooms must use different channels. In the case of IR, there are no such issues because walls are opaque to light. Another ALD is the induction loop system which uses an electromagnetic field to carry the sound to the user's ears with or without a personal listening assistive device. In this system, a loop of insulated wire, which might be worn around the neck or might encircle an entire room, is connected to a power source, an amplifier, and a microphone. An amplifier transmits the electrical signal from the microphone to the wire, and this electrical current creates an electromagnetic field that is picked up by the hearing aids or the cochlear implants with a telecoil feature. The users sitting within the loop system can pick up the speaker's voice or TV without distortion and no background noise. The loop is fully adaptable to television, radio, stereo, and tape recorder (Aussie Deaf

Kids 2015; Dillon 2012; Hinman et al. 2003; Inglehart 2002; NDCS 2017a, b; Zanin and Rance 2016).

Further, ALDs are digital transmission technologies that use increased audio bandwidth (up to 7300 Hz) and frequency-hopping to prevent electromagnetic interference and therefore improve the SNR for the listener (Wolfe et al. 2013). Finally, Bluetooth technology allows two electronic devices such as a cell phone, a computer, the TV on one hand, and a hearing aid or a cochlear implant on the other to connect to each other (Hinman et al. 2003; De Raeve 2015).

Captioning

Three types of captioning that individuals who are DHH use are real-time captioning in classrooms, television captioning, and captioned telephones.

Real-time captioning in the classroom. Real-time captioning meets the communication access needs of some DHH students in classes with primarily hearing students. The provider of the service, who is often in the classroom next to the student(s) who are DHH, produces text as it is being spoken by the teacher or other students and displays it on a portable device so that the student can access instruction and, more generally, understand what is taking place in the classroom. In the two common real-time captioning options, the provider uses either a standard typing (QWERTY) keyboard with computerized word abbreviation expansion or a stenographic (stenotype) machine. A little used option, with greater promise for the future, is automatic speech recognition (Ruan et al. 2016; Stinson et al. 2008). The typing-based services often include a messaging feature so that student users, who are unable or uncomfortable using their voice, can ask questions or make comments by typing a message that the service provider can view and read aloud to the class.

Real-time captioning services may be provided in the classroom or remotely. If remotely, the speaker, such as a teacher, typically wears a Bluetooth microphone, and the spoken

message is delivered using either a cellular phone or Voice over Internet Protocol (VoIP) via a cellular or broadband Internet connection (i.e., Skype, Google Hangout). These services also support display of text on diverse devices (standard laptops, smartphones, etc.). Display of the text may be based on an easily downloadable app that runs on iOS and Android devices. To use the service, the user simply connects and then begins to use the service. Some services use a web browser for display of captions. Real-time captioning services usually distribute notes, or saved text, to students after classes (Cawthon et al. 2013; Stinson et al. 2014a). Notes produced by real-time captioning service and a note taker are different from each other. Notes produced with captioning are the saved transcript of the lecture, which may or may not be modified by condensing, bulleting, etc. Compared to this text, handwritten notes involve more rephrasing of concepts and greater condensing.

Real-time captioning is frequently a desirable option for students who are DHH because it helps them understand and learn classroom material by providing information that is permanent and distributing notes (saved text) that contain the actual vocabulary used by a teacher. Also, it helps them deal with the multiple visual demands of the classroom. Based on studies that compared real-time captioning with other services, the students learn the same amount or more with real-time captioning as with interpreting (Marschark et al. 2006; Stinson et al. 2009). Also, sometimes, students rate their understanding of the instructor higher when they receive this service than when they receive interpreting (Stinson et al. 2017a).

Television captioning. Television exerts a substantial influence upon children's learning and socialization. 85% of more than 50 million children in the United States watch television everyday (National Captioning Institute 1983). Children who are DHH watch television as often as children who are hearing do (Lewis and Jackson 2001; Liss and Price 1981). Today, television programs may be viewed with captions. These captions are a text display of the audio component of the television program, which is generally

displayed at the bottom of the television screen (Lewis and Jackson 2001). In order to see these captions, which are generally transmitted in closed format, the viewer must set the caption decoder, which is contained in virtually all television sets, so that it displays captions. A major reason for production of captions is to provide individuals who are DHH access to the audio component of the program. Open captions can be distinguished from closed captions. Open captions are displayed to all individuals who view the video. Closed captions are only viewed when the caption decoder is set to display captions on the screen.

Despite the barriers that individuals who are DHH face in becoming a proficient reader, research has indicated that captions are beneficial to them (Qi and Mitchell 2012). This is consistent with the regular use of various forms of printed information by individuals who are DHH (Stinson 2010).

Researchers have attempted to identify ways of increasing the comprehension of captions by individuals who are DHH, but research to date does not clearly indicate that factors that might be expected to facilitate comprehension, such as caption rate and linguistic complexity, consistently increase comprehension. Reading proficiency has been found to affect comprehension of captions (Braverman and Hertzog 1980; Burnham et al. 2008).

Captioned telephone. Telecommunications relay services allow persons who are deaf, hard of hearing, and deaf-blind or who have speech disabilities to place and receive telephone calls. A communication assistant relays the call back and forth between the person with a disability and the other party to the call. There are different variations in how the service may work. In one option, Internet Protocol-Captioned Telephone Service (IP-CTS), persons with hearing loss are able to almost simultaneously hear and read the communication from the person with whom they are having a telephone conversation. The communication assistant listens to what the party being called says and produces text, such as with a stenotype machine or through re-speaking with automatic speech recognition that automatically

transcribes these words, with the words reappearing nearly simultaneously after they are being spoken by the other party.

Through text-to-voice telecommunications relay services, an individual who is DHH communicates in text what she/he wishes to communicate to the other party, and the assistant repeats in voice what the user has typed and types for the user who is DHH the hearing telephone user's response. Users who are DHH may view telephone captions through a special phone that displays captions, through a downloadable application on a mobile device or a website. These services are often delivered via the Internet. Some countries that provide this service also tend to support it with a small surcharge on users of telephone services (FCC 2017; Power et al. 2007).

This service can enable individuals who are DHH to more effectively use a telephone at their home or jobs. Individuals who use a form of captioned telephone, as opposed to video relay service with a signing interpreter, tend to be individuals who are DHH with relatively good proficiency in their native spoken language (e.g., English), such as those with an acquired hearing loss. When these individuals prefer to communicate by speaking and have enough residual hearing to at least partly be able to follow the conversation of the other party on the phone, they are likely to value using the IP-CTS service (MITRE 2016).

Currently, just more than half of the users of telephones who are DHH are satisfied with use of the phone with the assistance of their hearing aids (MITRE 2016; Payton et al. 2017). In addition, these users report that hearing aids provide on average only 55% benefit during phone conversation (Kochkin 2013).

Text Messaging to Facilitate Communication in Small Groups

A new area of work is an accommodation to facilitate communication between individuals who are DHH and individuals who are hearing in small groups who work together on a task.

These small group situations are quite common. At school, cooperative learning and collaboration learning promote deep, meaningful learning (Cohen 2002; Esmonde 2009; Lunetta et al. 2007; Pintrich et al. 1993; Schuell 1996). However, the benefits of collaboration in school are only possible when students successfully exchange ideas, comments, and insights. Students who are DHH often face communication challenges because the provided services are not adequate for the situation. Furthermore, even in classes where there is a range of services such as professional sign language interpreters, real-time captioning, and note takers, if more than one individual who is DHH attends this class and they participate in more than one group, there may not be enough interpreters to support each of these students. Often mobile devices can help communication in small groups with students who are DHH and students who are hearing. A technology that produces typing or drawing for all group members to see can help level the playing field when DHH students participate. Because typing and drawing are visual and remain visible longer than speech or sign, these are reliable forms of communication.

This text-based communication may be face-to-face or online. The use of messaging and shared documents, such as in Google Docs, has emerged with the growth of wireless Internet services and widespread use of mobile devices. Messaging applications, such as iMessage, may enable participants to more easily communicate with each other longer, relatively complex statements compared to using paper and pencil, gesture, pointing, etc. This form of communication is more likely to occur when a sign language interpreter is not available, when hearing participants do not know sign language, when the DHH participants cannot readily understand spoken communication of the hearing participants through speech-reading and residual hearing, and/or when the DHH individual's speech is unintelligible. A new way for hearing participants in groups to produce messages is through automatic speech recognition. Hearing users voice into a Smartphone, a tablet computer, etc., and the automatic speech recognition engine converts

their spoken messages into print for viewing by all participants with devices networked to share the conversation (Stinson et al. 2017b).

An experimental study of the effect of an iMessage intervention in a situation where two of the participants were DHH and two were hearing provided evidence of the effectiveness of technology in facilitating communication between DHH and hearing individuals in small groups. Results indicated that when iMessage was available, the two students who were DHH stopped signing, the two students who were hearing stopped talking to each other, and everyone, instead, communicated primarily with the whole group through the technology (Stinson et al. 2014b). In addition, research has found that students who are DHH are now increasingly using technology, such as cell phones and laptops, to communicate with students who are hearing in small groups (Stinson et al. 2014b, 2017b).

Video Streaming Communication Technologies

Video streaming technologies allow individuals who are DHH who use a sign language to communicate with other individuals who are DHH and with individuals who are hearing and use sign language over the Internet through video chat and through video relay services.

Online video communication technologies. Video chat, where the participants simultaneously communicate via sign and/or voice over the Internet is a technology that individuals who are DHH often use with each other or with a hearing individual. Examples of video chat include Google Hangout, Skype, and FaceTime. Some educational programs use this technology for an individual with expertise in a field to provide tutoring to a student who is DHH (Elliot et al. 2013). Video chat may be supplemented with simultaneous sharing of photos and documents. When video chat is used for tutoring, it may use virtual whiteboards such as Conceptboard to share this information. For example, in tutoring in mathematics, tutor and tutee may exchange written board work related to solving the problem

by using Conceptboard, or alternatively they may focus their web camera on the mathematical notation that they handwrote on their own whiteboards or paper. Individuals that are using video chat may sometimes switch to using text messaging, such as when there are technical issues with the video (CAT 2015; Elliot et al. 2013). An advantage of the Google Hangouts software application relative to other video chat programs is that it allows multi-platform communication (e.g., video feed, document sharing). Individuals who wish to communicate by sign with each other use video chat to communicate with each other for a variety of purposes, such as for social communication, in addition to using this technology for education.

The idea of using video chat for education of students who are DHH is quite new. The limited evidence to date indicates that this approach is usable and effective and that online tutoring with signing may work as effectively as face-to-face tutoring with signing in assisting students who are DHH (Elliot et al. 2013; Lissaman et al. 2009; Richardson 2009).

Video relay services. Video relay services (VRS) are implemented with the goal to ensure effective phone communication between signing deaf persons and hearing persons. Furthermore, video relay services are provided to enable individuals who are DHH and individuals who are deaf-blind make telephone calls with hearing individuals that function as well as the phone calls between individuals who are hearing and communicate though speech. While captioned phone services are used by individuals who are DHH and who want to use captions to help access the spoken communication over a phone, video relay services are used by individuals who are DHH and who communicate via a sign language. Video relay services use video streaming technology so that the individual who is DHH is able to view a communication assistant who signs the spoken message produced by the hearing individual that the DHH person has called; in addition, the video technology enables the communication assistant to view the signing of the DHH individual so that the assistant can relay the DHH person's signed message to the hearing party on

the phone. The typical VRS communication sequence consists of (a) the user who is DHH signing a message to the VRS communication assistant, (b) the communication assistant relaying this message to the hearing user participating in the phone conversation by converting it into a spoken message, (c) the hearing user replying to the message produced by the user who is DHH with speech, and (d) the communication assistant relaying this message to the user who is DHH by converting it into a signed message. Both the individual who is DHH and the communication assistant use specific software on a computer and a computer web cam to enable this communication (FCC 2017; MITRE 2016; Power et al. 2007). Some countries offer these services through a small charge that is included in the telephone service charge of all of the users of phones in a country. These services are important for enabling persons who are DHH to make all the kinds of phone calls that hearing individuals make: e.g., for work, medical services (appointments), shopping, communication with friends and family, etc.

The limited research and experience in provision of services indicates that while individuals who are DHH, who are primarily users of a sign language, benefit from video relay services and that these individuals prefer video relay to a text-based telecommunication service, video relay lags behind technological advances, and it is not at a level that satisfactorily meets the needs of users who are DHH (MITRE 2016; Steinberg et al. 2006).

Alarm and Alerting Devices

A wide range of alerting or alarm devices are available with a number of features that may help individuals who are DHH to wake up, keep track of time, and be notified of various happenings. Sometimes these devices can inform or alert individuals who are DHH of quite risky happenings, such as incoming weather that is potentially dangerous. An alarm device might have various features such as adjustable volume, vibrating pads, display screen size, flashing

lights, or a combination of these features. Also, the alarm device might sit on a table or be portable. Furthermore, alarm systems may be connected to various household devices such as doorbells, smoke alarm, kitchen timers, and telephone alerts. In addition, instead of using separate notification devices, such as an alarm clock, personal alert systems can inform individuals who are DHH about various sounds around the home such as those created by a telephone, doorbell, smoke alarm, or an alarm clock by being wirelessly connected to each item. When one of these devices is activated, it sends a signal to the personal alert system, which may provide a visible or vibrating warning, such as on a wristwatch, or phone (Kim and Kim 2014; NDCS 2017).

In addition, current mobile devices may capture vibration signals nearby or a spoken public announcement that are poorly accessible to people who are DHH. Vibratory signals through mobile devices have proved to be effective when their duration is long, around 13–14 s (Harkins and Bakke 2011). Of course, it is important to stress that current streaming technology is able to link several devices, including mobile or non-mobile ones, to the user's personal hearing devices (hearing aids and cochlear implants) (NDCS 2017). That is, the alert signals, which are usually auditory ones, cannot only be sent to the mobile device as vibrating signals, but they also can be directly streamed to the hearing aids or cochlear implants and be perceived as auditory signals by users with functional hearing.

Conclusion

Assistive technology can play a major role in the access and participation of individuals who are DHH in daily life, in a variety of environments, such as home, work, school, playgrounds, sport activities, social events, and cultural centers. There is a wide range of assistive technologies that can benefit different users depending on their functional hearing, the way that they communicate, and the environment where they are. Nevertheless, despite the positive role of assistive

technology, many individuals who are DHH do not use them.

The use of assistive technology has been limited due to psychosocial factors such as social stigma, low self-esteem, and cosmetic appearance associated with the use of these technologies, as well as to difficulty in adjusting to using a new technology (Cienkowski and Pimentel 2001; Rekkedal 2011). Such concerns seem to have been addressed lately by the mobile phone technology, which allow users to control their hearing aid or the cochlear implant through their mobile phone. In this way, users do not need to carry extra devices, and they also avoid the social stigma that concerns some of them because the use of a mobile phone is common (Compton-Conley n.d.). Another reason for the low use of assistive technologies is that in many countries these devices are not available or are costly. Also, the regulations regarding accessibility and the implementation of these regulations vary from country to country. Although personal amplification systems, such as hearing aids or cochlear implants, seem to be widely used, assistive technologies are not always so widely known or provided.

Therefore, in order for these technologies to become more widely used, they need to be broadly available, and additionally there is a need for the mandatory application of Universal Design principles that would address the needs of clients with different characteristics and skills including individuals who are DHH (Office of Educational Technology 2010; Varzhel et al. 2017). Under Universal Design, assistive technologies will be included in the planning of buildings, events, learning programs, and all products ensuring or facilitating the access of individuals who are DHH.

Cross-References

- ▶ [Assisting Students with Learning Disabilities Through Technology](#)
- ▶ [Assistive Technology and Inclusion, Philosophical Foundation](#)
- ▶ [Distance Learning](#)
- ▶ [Online Teaching, Emotions, and Emoticons in Computer-Mediated Communication](#)

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Assisting People with Autism Spectrum Disorder Through Technology

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Introduction

This entry seeks to provide a review and overview of technology that has been used to support autistic people. The aim of this entry is to provide an overview of technology used by autistic groups contextually and historically. Materials covered will include virtual reality technologies, touch screens, and more traditional media types (i.e., multimedia). The entry will include a historical overview of the field and provide some detailed explanations of technologies that have been used, mainly in scientific literature. In addition to this, the entry will explore autism and paradigms of exploring the field of technology used by autistic people. Finally, the entry concludes with some views, perspectives, and the potential for future work in this area, coupled with messages for practitioners and ways that technology can be most fruitfully used with, by, and for autistic groups.

Autism and Autism-Based Paradigms

Autism spectrum conditions (ASCs) are pervasive and enduring conditions, characterized by a qualitative impairment in social functioning and communication and restricted or stereotyped behaviors. Autism is also described as a neurodevelopmental condition characterized by core differences in social communication, interaction, and repetitive behaviors across a variety of contexts. In terms of autism being described as a “spectrum,” there are ways that this has been contextualized in recent years. Most recently, a “spectrum” is referred to as people who meet the main criteria (outlined above) in addition to having associated learning difficulties – or not. So terms such as “high functioning” and “low

functioning” are used and associated with autistic people without or with learning difficulties (respectively). This entry takes the position that using terms such as “autistic people” is preferred by the autistic community and as such will use this language.

In terms of its impact, the National Autistic Society predict that “Around 700,000 people in the UK are on the autism spectrum [...] together with their families, this means autism is a part of daily life for 2.8 million people” (National Autistic Society 2018). This number of autistic people reflects about 1:68 within the UK and, in studies undertaken in parts of the USA, can rise to 1:56. In addition, the condition is reported more in males than females with about four in every five autistic people being male. Recent evidence tends to suggest that one reason for this male/female ratio could be due to females being better able to shield their condition. Notwithstanding various limitations, discussions, perspectives, and reasons related to the data above (and either way), there is a growing population of autistic children and adults. As diagnosis, support, and educational provision are improving, there is an increasing need to identify ways to support key areas related to education, support, and transition from adolescence to adulthood.

Despite increasing diagnoses and better recognition and support for autistic communities there are still limited positive outcomes for autistic youths and adults. There remains a significant gap, for example, in employment prospects for autistic adults. With data from the UK, for example, reporting about 32% of autistic people in paid employment (this falls to 16% for data related to full-time employment), there is a specific and urgent need to consider ways to help improve this. A number of approaches that have been identified in recent years include (1) identifying and positively utilizing the strengths of autistic groups, (2) educating employers and others as to how autistic individuals can successfully be integrated into workplace settings, and (3) employing a range of technology tools to help assist successful transition routes into employment. These factors can also be said to apply to a range of other contexts including education,

socializing, learning, and training, to name a few. The specific focus of this entry is to present ways in which autistic people are engaging with and using a range of technology tools to help assist in a variety of ways. The following sections will outline:

1. Paradigms and perspectives of evaluating and using technology for autistic groups
2. Why technology has been seen to be a good fit for autistic users
3. Types of technology use for autistic users
4. Conclusions and future directions

Paradigms and Perspectives

It is important to understand that technology applied to autistic contexts has been situated in a range of perspectives or for the purposes of research: paradigms. This is useful to briefly mention as it *can* cause tensions between not only the types of data that are used to report studies across paradigms but as it can also raise concerns for terminologies and the applied use of technology. In medical-based perspectives, autism has been seen as a disorder and in many cases reported as requiring “interventions” to help improve the skills and therefore outcomes of autistic people. Technology-based research within this paradigm has sought to develop interventions with a view that autistic individuals can have gaps/problems in their condition managed. These examples have highlighted a deficit-based model of autism.

However, and in recent years, there are other paradigms and perspectives that have sought to develop the use of technology as a way to support, develop, and enable autistic people. These types of studies and projects are situated more closely, in many cases, toward a socially integrated, progressive, and accepting views of autistic people. This is not to suggest that medical-based ideals have not been accepting or socially progressive, but rather that they tend to focus on fixing deficits in individuals. Constructivist and interpretivist models accept differences and try to situate their work within understanding how autistic people view the world and how others view them. In

fact, most recently (2018) there have been initiatives toward recognizing autistic individuals’ strengths and how these can be harnessed and utilized within a range of opportunities. The role of technology in constructivist domains tends to seek ways of augmenting and adapting the lives of autistic people. For more on this perspective and overview, please refer to the work of Milton (2014).

Next, various types of technology used with/by/for autistic groups will be introduced, outlined, and discussed.

Why Technology and Autism?

Before discussing types of technology used by, with, and for autistic groups, the following table provides an overview of the technology discussed in this entry along with definitions related to these technologies (Table 1).

Key features of virtual environments have been cited as having potential benefits for autistic individuals as they can be individualized, controllable and predictable and offer “safe spaces” for users to learn new skills (Parsons and Mitchell 2002; Kandalafi et al. 2013). This means that autistic individuals can practice interactions within a realistic environment that can be programmed to reduce sensory and social inputs to a manageable level.

The publication of several conceptual and state-of-the-art reviews in recent years has focused the debate more widely on issues relating to the use of VR by, and with, autistic individuals (see Bellani et al. 2011; Parsons and Cobb 2011; Parsons 2016; Bradley and Newbutt 2018). In addition, the immersive nature of virtual environments (VEs) has been shown to enable a sense of presence for autistic adolescents (Wallace et al. 2010) as well as providing a motivating tool for learning (Parsons and Mitchell 2002). There is evidence that the ability to individualize, rehearse, and repeat social scenarios across different contexts has afforded opportunities for the generalization of social skills learned in VE to everyday life interactions (Didehbani et al. 2016; Parsons and Cobb 2011; Tzanavari et al. 2015).

Assisting People with Autism Spectrum Disorder Through Technology, Table 1 Key terms, abbreviations, and definitions used in this entry

Term in full	Abbreviation (if applicable)	Definition with reference point
Virtual reality technology	VRT	This is used as an umbrella term to describe the technologies below and in general, encompassing all virtual reality-type experiences
Virtual reality	VR	Virtual reality specifically refers to the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors (ref: Google.com)
Virtual environment	VE	A computer-generated, three-dimensional representation of a setting in which the user of the technology perceives themselves to be and within which interaction takes place (ref: Dictionary.com)
Collaborative virtual environment	CVE	The same as a VE, plus the ability to collaborate with others within a 3D simulated space
Single virtual environment	SVE	The same as a VE without the ability to interact with others
Virtual world	VW	A virtual world is a computer-based online community environment that is designed and shared by individuals so that they can interact in a custom-built, simulated world. Users interact with each other in this simulated world using text-based, two-dimensional, or three-dimensional graphical models called avatars (ref: Techopedia.com)
Head-mounted display	HMD	A type of computer display device or monitor that is worn on the head or is built in as part of a helmet. This type of display is meant for a total immersion of the user in whatever experience the display is meant for, as it ensures that no matter where the user's head may turn, the display is positioned right in front of the user's eyes (ref: Techopedia.com)

Note: Link to full-res images that are included, is below. <https://www.dropbox.com/sh/20252dtc1a14kmp/AAA0D80gWafQmkYdwsf2Ooy0a?dl=0>

The recreation of realistic settings and contexts by researchers and developers has enabled skills to be learned and reinforced in VE in ways which were not always possible or, more problematic, in real life. A range of different scenarios have been designed to enable autistic individuals to learn skills that may be supportive of independent living, positive social interactions, or maintaining their personal safety. For example, researchers have developed VE that recreate celebrating with a friend and meeting strangers (Kandalft et al. 2013) or crossing a road safely (Strickland et al. 1996) and learning social conventions (Parsons et al. 2006).

This research indicates that VRTs have valuable potential for both support and the education of children, young people, and adults who are autistic. Many studies show promising results regarding users learning and generalizing new

skills and knowledge and showing changes or developments in their responses over time (Parsons 2016). However, there remain significant challenges for testing the relevance and applicability of VR for autistic children in educational contexts.

Within the field of assistive technology (AT), various virtual technologies have been used with the aim to help and assist autistic people in a variety of ways. They have been used in ways to help enable spatial awareness (Strickland et al. 1996), to help understand facial expressions (Fabri and Moore 2005), to understand social skills and social awareness (Parsons et al. 2005; Parsons 2007), and as a tool to help support social cognition training (Kandalft et al. 2013). Additionally, Alcorn et al. (2011) have undertaken work in virtual environments to help facilitate joint attention cues. Studies within the area of

virtual reality technology (VRT) have mostly reported positive outcomes and highlighted how, in many cases, people with autism have adapted to VE interfaces (Parsons 2007; Guldberg et al. 2010), used VR with comfort and enjoyment (Strickland et al. 1996), developed social skills (Parsons et al. 2005), and found comfort in the communication afforded by VE interfaces (Fabri et al. 2004). In addition to this developing evidence-based, screen-based media is also something that research has concluded autistic people can be attracted to, in some cases more so than their typically developing peers (Mazurek and Wenstrup 2013). This highlights perhaps a preference for the use of material presented through screen-based media formats. For example, and as Mazurek and Wenstrup (2013, p. 1265) report: “Children with ASD spend approximately 62% more time watching television and playing video games than engaged in non-screen activities (including reading, studying, spending time with friends, and engaging in physical activities).” This is also a view previously reported by Mineo et al. (2009).

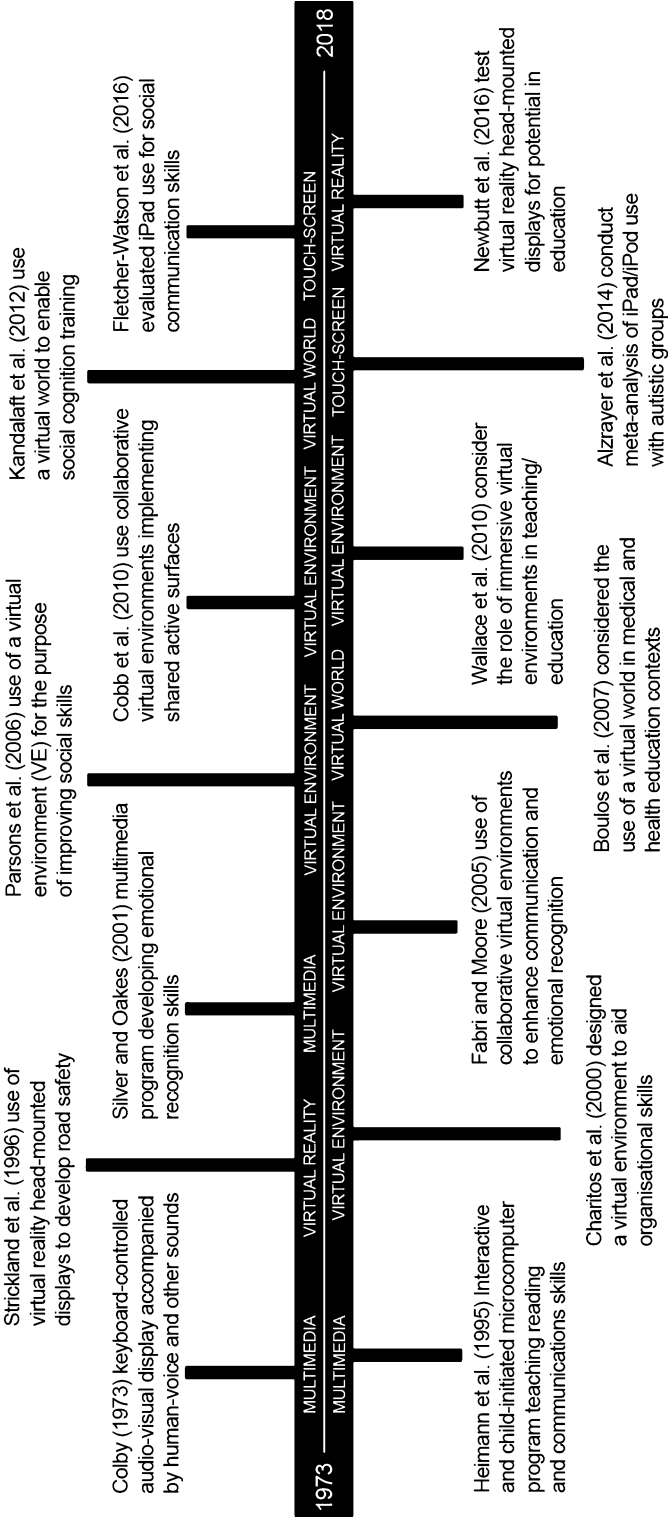
Examples of Technologies Used to Support Autistic Groups

This section seeks to identify and outline a range of technology tools that have been used by, with, and for autistic groups. Before moving onto this, the following figure (Fig. 1) provides an overview of the timeline for technology used with autistic groups. This is situated within the evidence-based research conducted over a period of time (1970s–2018). This is not meant to represent a detailed overview, but rather some key points when specific technologies have been used, applied, and evaluated with autistic individuals and groups.

While Fig. 1 provides a visual representation of key technologies across the last 40 or so years, the following sections aim to provide a more detailed overview and review of these technologies and where/how they have been applied for autistic users.

Virtual Environments and Collaborative Virtual Environments

Initially within the area of virtual reality technologies (VRTs), Strickland et al. (1996) presented an early study that assessed the effectiveness of virtual reality (VR) as a learning tool to engage autistic children; their study was primarily designed to determine if autistic children would tolerate VR equipment and respond to a computer-generated world. They considered the differences between VR and computer programs, the level of interaction with computer-generated images, and independence in determining motion and objects in a VR world as a way to present real-life experiences. The use of VR for autistic children was considered, based on sensory problems, lack of generalization, visual thought patterns, individualized treatment, and responsiveness to computer technology. The aim of the study was to help children with autism learn how to cross a road safely. They used VR helmets to immerse the users in a 3D environment, so that users could identify cars, the colors of objects, and how they were moving. The children were presented with various scenarios to determine generalization and were asked to “walk” into the scene and interact with signs. Conclusions gained from the study suggested that the two participants were able to interact with the environments successfully (accepted the virtual helmet, tracked in-world objects, moved their bodies and heads, located in-world objects, and moved toward them). In addition the study suggested that the participants appeared to become immersed (labeling in-world objects and moving their bodies interactively). These aspects tended to suggest that VR afforded far-reaching advantages to autistic children, including encouraging interaction, exploring, and learning. A limitation of the study was the small number of participants included; while two children accepted the use of VR devices (helmet, joystick, gloves, etc.), it does not follow that others would. Newbutt et al. (2016) readdressed these points later (in 2016). This will be discussed in later sections of this entry.



Assisting People with Autism Spectrum Disorder Through Technology, Fig. 1 Overview aligning key technologies used with autistic groups since the 1970s to 2018

Building on the work of Strickland et al. (1996), Charitos et al. (2000) designed a virtual environment that was controlled by virtual reality input devices, to aid the organizational skills of people with autism. The study aimed to teach social skills through providing a virtual interface for people with autism to navigate through. Charitos et al. provided a series of reasons why computer-based systems are well suited for autistic people, based on the work of Murray (1997). Examples cited by Murray included being able to set clear boundaries and controlling the stimuli (through a step-by-step process). These both allowed for greater control and focus of material in the presentation and learning. Another advantage cited by Murray links to joint attention and restrictive context. These both, in some ways, play to the strengths of autistic people in that focus of interest can be taken into account in addition to restricting other sources of information. Overarching these aspects, Murray suggests that safety, flexibility, and adaptability can all be instilled along with a sense of prediction.

On this basis, Charitos et al. (2000) proposed designing a virtual environment to aid children with autism in undertaking everyday tasks. This, more specifically, pertained to “returning home” and builds on a traditional teaching practice used within the school. It was an aim of the project reported in this paper to “improve the potential for effective teaching” (Charitos et al. 2000, p. 150).

Interestingly, although not surprisingly, Charitos et al. arrived at similar conclusions to those of Strickland et al., including the notion that structured environments go some way to help users feel confident and that a range of input devices could be used. The work presented by Charitos et al., while including more participants than that of Strickland et al., still has limited participant detail which would help provide useful contextual data, helping us to better understand the study in the exploratory manner it is intended.

Elsewhere, Fabri and Moore (2004) developed a simple platform that integrates the use of images (avatar representations) and animated facial expression sequences, to help in the understanding of facial emotion and communication for users with autism. They present three stages to their

product: (1) avatar representations in isolation, to help initial emotional understanding; (2) prediction of emotions in contextual situations – own feelings and feelings of others; and (3) avatar emotional representation, paired with a selection of events. The tasks involved recognition of an emotion from a facial expression, selection of an expression to represent an emotion, and prediction of an expression. The user at stage 3 is required to select an event that may have caused an emotional response and is asked to infer their own emotion to that of another (cause and effect). In order to identify whether participants were successful in selecting appropriate emotional avatars for each section of their program, Moore et al. compared the observed responses of the participants to the questions against chance responding. The results showed that over 88% of participants performed above the level of chance. Moore et al. conclude that the study offers evidence that the majority of participants involved were able to interpret and understand the emotions of the avatars appropriately. This study demonstrates that people with autism have both the ability and predisposition to use CVEs and that they can, via this medium, identify emotion, apply emotion, and predict emotion from facial expressions (Moore et al. 2005).

This study does, however, offer clear evidence that using virtual animated facial expression can help autistic users to understand and decipher emotion. The study recognizes that a small minority of participants found it difficult to understand the emotions represented by the avatars, and for this reason, more details on the individual participants would have been useful, allowing greater insight into who CVEs could be most beneficial for.

Cheng and Fan (2008) also used a CVE to experiment with the representation of emotions for autistic children. This study included 2D image representations of 3D avatars, rather than 3D avatars as used in Parsons et al. (2005). In Cheng and Fan’s study, ten participants ranging from 5 to 17 years old were selected; they all had a local (school) diagnosis of autism. The study was focused on considering the role of expressive avatars used in conjunction with text chat communication or computer-mediated

communication (CMC). To investigate this aspect of CMC, the authors conducted an interview with the ten participants via the CMC program created for the purpose of the study. One of the primary aims was to judge how the participants with autism responded with text and expressive avatars throughout the communication process. In other words, they provided an interface that allowed users to talk one-to-one, through the medium of text and visual representations of faces. Each of these faces displayed a different emotion. They were modeled in 3D, then rendered and exported as 2D images. Cheng and Fan concluded that eight of the ten of participants were able to successfully use the system to identify emotion as represented by a graphic. Moreover, the participants were able to interpret the emotions of others through the system.

Another study that builds on the work carried out by Strickland et al. (1996) and Cromby et al. (1996), and adds to limited knowledge in the field, is that of Parsons et al. (2006), where newer and different technology is applied. The study of Parsons et al. (2006) involved the creation of a virtual environment (VE) for the purpose of improving social skills in two autistic children. This study included two children within the high-functioning range (i.e., without ID). However, Parsons et al. introduce a VE that involves navigating through simple scenes (a café and a bus stop), rather than presenting a one-to-one communication tool (building on the findings of Cobb et al. 2002). In other words, the users were able to navigate through an environment or space as part of the simulation. The scene includes other characters, who are passive, but are pre-programmed to respond to user input. In their analysis, Parsons et al. consider five areas for review and discussion: (1) repetition of response, (2) physical and literal interpretations, (3) treating the VE like a game, (4) putting learning into practice, and (5) recognizing changes and usefulness. Repetition of response was an area of the research that provided mixed results. Both users would navigate through the café scene in exactly the same way, individually, each time they approached the tasks, although one of the

participants would maintain their route through the scene despite encounters with chairs, tables, and other objects.

Parsons et al. (2006) also report some repetitive statements/verbal responses, although the participants did change some responses in the VE, in particular choices of food ordered and when asking if they could sit down to eat their food. Furthermore, the participants sat in different places each time they used the environment, suggesting that they were “responding differently to the changing demands of the VE” (Parsons et al. 2006, p. 13). Literal interpretations were an issue for the participants: one of them could not understand why, for example, they could not sit in an empty chair when the person sitting at the table said, “Excuse me, that seat is taken.” The participant thus highlighted a problem with accepting that a seat can belong to a person socially. However, after repeating this several times, and with some help from the facilitators, the participant was able to understand the need to ask if a seat is taken, out of courtesy.

One of the main difficulties in using VEs, and in particular for autistic users, is in creating the perception of reality, so that the user can identify and provide natural responses. It was noted by Parsons et al. that the participants viewed the VE as a game and would not therefore interact as they might in real life. However, it was observed that there were occasions when the participants would apply real-world and appropriate actions to the VE. A specific example relates to the choice of seats on a bus – the participant chose a seat that had enough legroom and one that was facing in the preferred direction. This perhaps shows how immersed the participant had become and that they did view the VE as a “real world.” A similar finding, but with more participants, was reported in an earlier study by Parsons et al. (2005).

In sum and taken as a whole, the role and potential of VRTs and specifically VEs, for autistic users, has been shown to have some benefits and possible useful application for skills development, specifically testing social situations and visiting places. Both of these contexts can

be designed in ways to reduce cognitive pressures and real-life consequences or indeed any other types of interactions. This, along with the predictable nature of using a computer simulation, can provide a suitable or preferred space for autistic groups. The next section will briefly discuss virtual worlds and how these have been used by and for autistic users.

Virtual Worlds

Boulos et al. (2007) considered the use of Second Life (a type of virtual world) in medical and health education. Their article helps to provide a clear indication of the potential of VWs in health-related conditions – in an educational context. The authors discuss and present two case studies of recent and successful VW endeavors, in Second Life (Healthinfo Island and VNEC – Virtual Neurological Education Centre), and are able to present a detailed insight into the advantages afforded by the platform. These include the use across a distance-learning education model and for older people and people with physical disabilities; real-time social networking and state-of-the-art graphical representations are also highlighted. Boulos et al., in addition, identify several challenges pertaining to the use of VWs. These include Internet addiction, gambling, violence, trust, identity, copyright, and vandalism. These all relate to ethical concerns and are something all VW studies need to address and consider for their user groups, more broadly.

Recently, Stendal and Balandin (2015) report on the use of Second Life and therefore VWs. Here they suggest that “people with ASD enjoy using a virtual world and may feel more comfortable communicating in the virtual world context than the physical world” (p. 1591). They also highlight several self-reported affordances of VWs including:

- Autistic people enjoy using a virtual world and can feel more comfortable communicating in the virtual world context than the physical world.

- Virtual worlds offer a venue for autistic people to be a part of a virtual society.
- Virtual worlds offer an arena for autistic people to meet their peers on equal terms, not being dependent on social cues, which in the physical world can be a barrier for this group (Stendal and Balandin 2015).

These are similar to findings reported by Newbutt (2013) who also found that autistic children reported preferences for using text chat to communicate with others (their peers and teachers), in a virtual world. The fact that text chat can be undertaken at the pace of the individual, and that extra thought can go into what they would like to say, helps, especially autistic individuals, in communicating with more confidence.

Virtual worlds (VWs) also offer potential for autistic users, and in fact one of the largest, Second Life, has many registered users who have such conditions (Salman 2006). However, to date few, if any, formal studies have been carried out to assess the impact such environments are having on users with autism, even though virtual worlds have contributed to this field of study and could provide a form of assistive technology.

In a brief correspondence, Fusar-Poli et al. (2008, p. 980) hypothesize that Second Life could be used to “develop social and communicative skills of autistic people.” They go on to outline the same affordances as Cobb, Parsons, Moore, and Fabri, stating that “. . . it allows anonymous social interactions, and provides high levels of social interactivity but without complex linguistic and social-behavioral processing necessary for face-to-face conversations” (Fusar-Poli et al. 2008, p. 980). Further, Fusar-Poli et al. suggest that it “levels the playing field for autistic people,” in that it offers a new space to rehearse social skills. This last statement, although a value statement, does suggest that people with autism and related conditions can enter VWs without any preconceptions or assumptions placed upon them. Fusar-Poli et al. also say that a secure and safe space is needed in which social mistakes can be made so that a sense of collaboration and

community can be established. The authors propose Second Life as an ideal tool for allowing participants with autism to benefit from the affordances mentioned.

In a specific example of the use, potential, and application of VWs, a charity (Autus; <https://www.autus.org.uk>) has implemented the use of a VW to help connect and open employment opportunities for autistic groups in the UK. Here they have designed virtual job centers (in a virtual world) to help provide access for autistic groups who might find it difficult to access resources in real-world job centers. There are other such initiatives designed and implemented by the group, all building on the affordances of VWs for autistic groups. Figure 2 provides an example of how this looked, visually.

It is through the affordance of VWs that can provide a fruitful space for autistic users to develop confidence and test situations out. The use of text chat and body movements (and facial expressions) can all be used as/when to help open modes of communication in VWs. This has been seen to be a positive effect in the work of Autus (above) and the work of Newbutt (2013).

More recent developments have provided newer lines of inquiry (i.e., touch screen devices)

and renewed lines of inquiry (i.e., VR and HMDs). The next two sections review work in the area of both touch screen devices and HMDs.

Touch Screen Devices

The arena of touch screen devices applied to autistic groups is something first investigated since the introduction of affordable and freely available touch screen technologies, namely, the iPad. Since then many studies have sought to investigate the possibility of how iPads (and other touch screen devices) can be used to develop communication, social, and initiation skills. For example, and recently, Xin and Leonard (2015) investigated the role of an iPad in developing communication skills in “three 10 years old learners diagnosed with autism who present little or no functional speech” (p. 4154). As a result of using an iPad, the authors concluded that all students increased initiating requests, responding to questions and making social comments in both class and recess settings. This provides some positive and helpful insights to the way that iPads and touch screen technology can be used to help aid communication endeavors of autistic users.



Assisting People with Autism Spectrum Disorder Through Technology, Fig. 2 Example of interface developed by Autus for an employment project. Using a

VW to help provide access to employment services, removing the need to visit a real-world job center (in the UK)

However, and as with many of the studies already reviewed, the sample was very small and so generalizing across populations is impossible; therefore, the study is mainly contextualized within the details of the specific project.

In earlier work, Alzrayer et al. (2014) surveyed all previous (previous to 2014) studies conducted with autistic users related to touch screen devices. They found that “tablet-based devices, especially iOS devices (i.e., iPad and iPod Touch) were highly effective in increasing the communication skills of individuals with autism” (p. 179). In addition to positive reported outcomes for communication, the authors found that touch screen devices “also have positive effects on decreasing challenging behaviors” (p. 189). This started to provide some insights that suggest touch screen devices not only have educational outcomes for autistic users but that they could also be used and implemented as a way to help calm users. However much more work is needed to validate both these suggestions.

In more recent work, Fletcher-Watson et al. (2016) undertook a randomized control trial of an iPad App to “evaluated a technology-based early intervention for social communication skills in pre-schoolers” (p. 771). The authors developed an app with the aim to develop specific outcomes for communication domains (reciprocation, social, words, etc.). Most interestingly, this study found that the “intervention did not have an observable impact on real-world social communication skills” and they suggested that “caution is recommended about the potential usefulness of iPad™ apps for amelioration of difficulties in interaction” (p. 781).

Therefore, it is evident that the possible potential of touch screen devices is mixed and evidence is contradictory. The work of Fletch-Watson and colleagues included a large sample, larger than work carried out previously. However, it should be underlined that this was only the case for the app that the authors used in their study – it does not mean all apps would yield the same results.

Despite the range of evidence associated with touch screen devices, there should remain positive attitudes toward their use for autistic groups. At a very fundamental level, touch screen devices

provide ways for nonverbal users to effectively communicate with caregivers and other people they need to communicate with.

Virtual Reality Head-Mounted Displays (VR-HMDs)

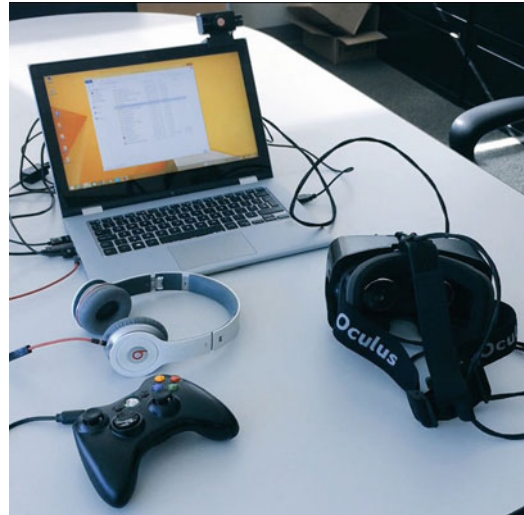
This technology has recently (2016–2018) become relevant and of interest – again – as it was first used in 1996 by Strickland and colleagues. They used the technology as a tool for teaching road safety and also to assess whether autistic children would be willing to wear a large HMD. However, the work of Strickland et al. (1996) was based in a lab and involved only two children, who were both encouraged to use the technology. As there have been a range of HMDs since the introduction of the Oculus Rift™ and increase in content (i.e., software) via the Steam network (<https://store.steampowered.com/>), there was a sudden and interesting need to investigate the potential of this technology for autistic groups. This was especially timely as there were many reports (without evidence or data) suggesting that VR and HMDs were a good fit for autistic users. However, with so few studies, it was difficult to assess the potential of HMDs without first asking autistic users about their willingness to wear and experience VR, especially based on concerns around sensitivity concerns (i.e., wearing a headset) and possible side/negative effects of HMDs (e.g., sickness, eyestrain).

As previously mentioned, the acceptance of VR technology among users with ASD has been studied over the last decade. Although some studies have established a safe way/process for the use of VR technology among autism populations, the technology itself has evolved and advanced in many ways since earlier work of Strickland and colleagues. For instance, VR technology and the head-mounted display used to be only an extension of the traditional monitors, which merely increase the viewing size and the viewable angle. The users of these VR devices acted as a passive role and did not have control over what was presented to them. Much has changed in the VR arena. The interaction

components have since been introduced and integrated in the VR applications. For example, users can now use a joystick to browse and maneuver in the virtual space. In addition, more current head-mounted display can also capture and respond to users' head movement to simulate a real-world 3D experience.

In addressing the need for a timely examination of HMDs (the newer generation), Newbutt et al. (2016) asked questions in a study related to acceptance of HMDs for autistic groups (a range in terms of age and the spectrum; remembering this relates to associated learning difficulties – or not). The findings from this work provided insights of how an autistic group felt about wearing a HMD and experience a range of VR experiences and how they reported sense of presence, immersion, and negative effects. Results, using an Oculus Rift HMD, highlighted a general level of acceptance (100% willing to try the HMD on and experience two VR scenarios) and high levels of self-reported presence and immersion. Most vitally, negative effects (i.e., feeling sick, eye-strain, etc.) were reported as being very low. These results were reported across an age range of 17–53. The equipment used was portable and taken into a workplace setting. The equipment used can be seen in Fig. 3, while Fig. 4 shows more recent technology (HTC Vive) being used in a school (in 2018).

Currently (as of 2018), there is a plethora of head-mounted displays available for the general public to purchase and use in their daily life. Depending on the purpose and the affordable budget, one can select inexpensive VR goggle such as the Google Cardboard, which costs approximately 20 dollars a pair. The design of Google Cardboard is to insert a smartphone into a pair of goggles made of cardboard with two lenses to simulate the 3D immersive effect. Because of its low-cost design, there is no audio or interactive component built in for the device. Users merely use it to simulate a visual 3D effect. The more sophisticated options are also available such as Samsung Gear VR, HTC Vive, and Oculus Rift (ranging from \$400 to \$800 without associated gaming computer, currently about \$1300). These VR devices capture the user's



Assisting People with Autism Spectrum Disorder Through Technology, Fig. 3 Example of VR-HMD kit used in Newbutt et al. (2016) study, highlighting the size, portability, and unobstructive nature of HMDs in 2016. This equipment was tested in a center for autistic groups in the USA



Assisting People with Autism Spectrum Disorder Through Technology, Fig. 4 Example of an HTC Vive kit being used with an autistic individual in school, again highlighting the possible inclusion in school-based settings. This was trialed in UK schools

head movement and can be used to play video games.

Despite the potential of VR and HMDs, there are only six studies that comprehensively report of

the use and/or potential of HMDs for autistic groups. These are reviewed by Bradley and Newbutt (2018) and cover work reported in the following studies:

1. Adjorlu et al. (2017)
2. Bozgeyikli et al. (2017)
3. Cheng et al. (2015)
4. Mundy et al. (2016)
5. Newbutt et al. (2016)
6. Strickland et al. (1996)

The work covered in these studies includes acceptance, willingness to wear HMDs, and the potential for learning and transferring learning using HMDs, mostly reporting positive findings in this area. However, there are several gaps and opportunities that arise from reviewing this work.

Though several studies had an element of participatory research methodologies, only two explicitly sought feedback from practitioners about the intervention (see Adjorlu et al. 2017; Bozgeyikli et al. 2017). This type of information is valuable and would enable more robust recommendations to be made on the sustainability of educational interventions and approaches using -VR-HMD technologies within educational, health, or community settings. Furthermore, the inclusion of autistic individuals in the research was predominantly in the role of passive participants whose experiences of the interventions were primarily gained through quantitative data. It can be argued that the lack of qualitative data, i.e., interviews with participants, limits our understanding of how they perceive VR technology and the use of HMD. It is therefore important to evaluate both outcomes and the process of implementation of VR technology through the involvement and experience of autistic individuals and the practitioners who work with them.

The variance in both technologies used (including how realistic the VEs are, type of HMD, and how tasks were carried out) and the diagnostic features of the autistic participants supported the finding that “the state-of-the-art in the literature is that there is no single study, or series of studies, that has systematically unpicked and interrogated the ways in which these features

may combine to influence responding and understanding” (Parsons 2016, p. 153). As with other research in this field, there has been a focus on autistic children, young people, and adults who have average or above average IQs and at therefore autistic without intellectual difficulties, which means the findings of these studies may not be applicable to a wider range of autistic individuals. The heterogeneity of response to VR-HMD applications and experiences indicates a need for further research that should take account of both the characteristics of this population and the specific features, characteristics, and affordances of this technology, to consider how these features might best support and motivate them. The issue of veridicality is of importance in this context, and the results from the six studies were mixed. Promising results were reported by Newbutt et al. (2016), with participants showing high levels of engagement, spatial presence, and ecological validity within VEs. In contrast, participants gave a more nuanced response in the study by Bozgeyikli et al. (2017) and indicated that while they were immersed in the VR activity, they were aware it was not real. As such, more work is needed on how VR-HMD technologies can be designed and developed to act as an authentic real-world experience for this population.

Conclusion

The increase of multimedia computing within the area of educational support for children with autism has been the focus of much research, from the early works of Colby (1973) and Heimann et al. (1995) to the work of Silver and Oakes (2001). These published works examined specific skills that multimedia could address in the educational development of children with autism. Through such studies, an argument has been constructed, for the use of virtual environments in providing a unique affordance for users with ASCs. Scholars such as Strickland et al. (1996), Parsons et al. (2005, 2006), Wallace et al. (2010), and Cheng et al. (2010) have each explored the role of immersion, realism, engagement, and

learning within virtual environments. Building on this, Kandalafi et al. (2013) have provided a specific example of the role virtual worlds can play in social cognition training. Yet, there remains a limited understanding in the literature of users' perspectives with a range of technologies.

Overall, the area of technology used by autistic people, and the potential benefits they hold, is still at an early stage in terms of research. While this field was developed and initiated in the 1970s, there has been slow progress with limited evidence related to:

- What types of technology are most suitable for autistic people?
- How and when should technology be used?
- For what age groups and levels of associated learning difficulties should specific and particular technology be used?
- Where is technology best deployed and utilized for autistic groups?

So far these questions remain underexplored in research studies, and so evidence supporting these is difficult to locate. Moreover, if technology is to have real potential for autistic groups, there is an urgent need to address the what, why, where, and how questions if there is to be more upscaling and utilization of technology for autistic people. Addressing these questions will also help to enable key stakeholders to place technology in the hand of the people it can most benefit. At the moment this is not happening.

In addition, and as highlighted above, no studies have applied a longitudinal or mixed-methods approach to this area, something that would yield a far better picture in terms of the longer-term outcomes, frameworks for continued application of technology (updates, development, versions), and refined software/hardware that might be most suitable and applicable in a variety of contexts (school, home, centers, etc.).

The future for technology used by, with, and for autistic people remains positive, especially based on nearly 40 years of evidence using a range of technologies. By working more closely with autistic advocates, groups, and individuals,

the field will be better placed to design, develop, and deploy technology that is suitable, usable, and effective in the future.

Cross-References

- [Assistive Technology and Inclusion, Philosophical Foundation](#)
- [Game-based Learning](#)

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Assisting People with Physical Disabilities Through Technology

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Synonyms

Accessibility; Assistive technology; Augmentative and alternative communication; Physical access

Introduction

The term physical disabilities often refers to a broad range of disabilities of people facing difficulties in limitation on physical functioning, mobility, dexterity, or stamina. These may include orthopedic and neuromuscular disabilities (such as cerebral palsy, spina bifida, muscular dystrophy, rheumatoid arthritis, spinal cord injuries,

traumatic brain injury, multiple sclerosis, ALS, and other orthopedic difficulties inherent or acquired), as well as sensory disabilities (e.g., visual or hearing impairment), and chronic health issues, cardiovascular or respiratory difficulties. Furthermore, the complexity of a number of diagnoses of physical disabilities often involve identification of difficulties in various aspects and interrelated sectors of the human activity and quality of life. Hence, as Heward (2011) identifies, people with physical disabilities compose an extremely complex and heterogeneous population which is impossible to describe in a single set of characteristics and terms. Similarly the use of technology for addressing the needs of people with physical disabilities lies in a huge spectrum covering all aspects of everyday life such as sitting and positioning, mobility, transportation, physical accessibility, access to digital technology, communication, and learning and cognition, as well as medical devices for care and health conditions (e.g., assistive products for respiration, for dialysis therapies, etc.). For example, the ISO 2016 assistive technology classification holds an enormous list of assistive technology items that can be used for the needs of people with physical disabilities in all areas of life, including health, care and well-being, workplace, education, everyday life activities, and more (ISO 9999:2016 Assistive products for persons with disability – Classification and terminology, available at <https://www.iso.org/standard/60547.html> (accessed 20 February 2018)).

In order to maintain focus, as well as coherence with the structure and content of this volume, this present entry will mostly concentrate on particular aspects of the use of technology for people with physical disabilities (not including sensory disabilities as these are covered elsewhere in the volume), involving physical access to digital technology and connections to communication and learning. Specifically, the aim of this entry is to present examples of assistive technology products for the various needs of people with physical disabilities but also to identify and discuss methodologies and models of assistive technology assessment, issues of implementation, and barriers and opportunities. Previous research studies

through the years (e.g., Judge 2000; Copley and Ziviani 2004; Mavrou 2011a; Layton 2012; Mavrou et al. 2017) suggest that as the number of people using assistive technology increases, the following areas are highlighted as particularly significant: accessing assistive technology, matching needs of person to technology, funding for assistive devices and service provision, and training of professionals and family members. In the present entry, this discussion is further supported by an example of a research case study.

Technologies for Physical Disabilities: Examples for Access, Communication, and Learning

Historically the various definitions of assistive technology placed assistive devices in the framework of functionality and accessibility often leading to connections with physical disabilities and mostly physical access and mobility. Gradually these definitions developed through the social and human rights approaches to disability, indicating the role of assistive technology in reducing environmental barriers (Scherer 2005) and in promoting equality, quality of life, and participation (see definitions of the WHO 2017 and ISO 2016). Nevertheless, as mentioned earlier, assistive technology for physical disabilities is primarily connected to physical access and includes a range of low-tech or simple devices (e.g., walkers or pencil grips) to high-tech ones (e.g., power wheelchairs or digital communication systems) (Huang et al. 2009). In 2014 the World Health Organization launched the Global Cooperation on Assistive Technology (GATE) initiative which aims to actions that will promote access to “high-quality, affordable assistive products to lead a healthy, productive, and dignified life” for every person in need of assistive technology, targeting especially the low-resourced areas of the world (Global Cooperation on Assistive Technology (GATE) of the WHO, available at http://www.who.int/phi/implementation/assistive_technology/phi_gate/en/ (accessed 20 February 2018)). Among other activities in the framework of this initiative, a Priority Assistive Products List

(APL) was developed (WHO 2016), after a scoping review and a high range Delphi exercise. The list, which of course is not restricted, includes 50 priority assistive products and aims to provide the UN member states with a model from which to develop a national priority assistive products list according to national need and available resources. The majority of the products included in the list concern physical access and are very relevant to the needs of people with physical disabilities but at the same time beneficial for other groups of people facing different challenges. Nevertheless, the composition of the list indicates the significance of low- and high-tech assistive products for physical access and their relevance to the range of people that these are essential for.

Hence, in this section of the entry, an overview of the main assistive technology products is presented, identified as essential for physical disabilities (and not only) in the digital era. This overview includes discussion of digital technology access devices and augmentative and alternative communication for physical disabilities.

Access to Digital Technology

The growth of computer and digital technology led to the emergence of the field of human-computer interaction (HCI) and the researchers’ and developers’ considerations on the communication and interaction between humans (people as users) and the artifact (computers and technology). Researchers in the field of HCI study the ways in which humans interact with technology and how technology is designed to facilitate a meaningful and innovative interaction addressing the needs of each individual. Hence, the components of this interaction and the impact on the design of technology interface and the assessment of individual user needs have become a major part in assistive technology (Zaphiris and Siang Ang 2009). In simple computer science terms, the exchange/interaction between people and computers entails three basic aspects – input, process, and output – commonly translated into hardware and software applications. Nevertheless, Cook et al. (2008) argue that “the human/technology interface is more than hardware and inputs into the device.” Rather it entails other elements, which especially

in terms of physical access, include not only hardware for input but also elements of interaction in processing and exchanging information. As Veigl et al. (2017) suggest, nonstandard human computer interfaces are required for people with complex physical and severe motor disabilities, especially when these are a combination of difficulties that challenge the selection of a single access assistive technology tool. Hence, according to the (Cook et al. 2008) model (i.e., HAAT presented later in this entry), in assistive technology for physical access elements of control interface, selection set and selection method are considered, which are examined together with the desirable output (and outcome) as well as the advances of technology.

Control interface refers to the hardware used to operate or control a device, which for people with physical disabilities often includes alternative input devices. Examples of alternative input devices are *pointing* devices, such as ergonomic mice, trackballs, joysticks, head controls, or even keyboard keys and eye-gaze technology with mouse emulation software; *keyboards*, such as one-handed keyboards, large keys keyboards, customized overlay, and programmable keyboards; *touch screens and touch surfaces*, such as external touch screens, touchpads, and touch-operated mobile devices; *switches*, which are selection and input command devices that may be operated with different body parts and control movements; *voice recognition technology*, by which the user can control the device with voice commands; *eye-control technology*, with or without mouse emulation; and even *brain control (EEG)*, which seems to create new possibilities for HCI and mostly for people with physical disabilities.

Upon decision on control interfaces, in choosing assistive technology for people with physical disabilities, selection sets and selection methods need to be considered. According to Lee and Thomas (1990) and Cook et al. (2008), selection set is the items available from which choices are made, which can be presented in visual, auditory, or tactile modalities. In other words, selection sets may be letters (e.g., in the case of a keyboard as a control interface), braille (as tactile), auditory

scanning output (e.g., in the case of a switch as a control interface), and symbols (e.g., in the case of an augmentative and alternative communication system). As far as the selection method is concerned, this is defined as the basic method by which the user makes a selection that can be either direct or indirect. Direct selection (or direct access) is when the person identifies the target and goes directly to it by using voice, hand, finger, eye, or other body movement with appropriate control interface. Examples of direct selection for people with physical disabilities include the use of eye-control access systems, touch screens, pointing devices, voice recognition, etc. Indirect selection refers to selection methods where intermediate steps are involved (Cook et al. 2008). This is mostly relevant to the use of switches and scanning, where the possible targets are sequentially (in various modes) highlighted (by a visual or auditory signal or a combination) allowing the user to press a switch when the desired target is scanned. Scanning can be autonomous by the device, where speed, timing, mode, and other features can be customized or directed, where it is activated and controlled by the user through a control interface (same or other than the selection control interface) (Angelo 2000).

As the individual needs of each person with physical disabilities vary and are often complex, access devices (and control interfaces) require configuration in a number of aspects. For example, in pointing devices, adjustments include mouse control parameters such as click method, double click speed, dwell selection, pointer movement speed and sensitivity, pointer precision, size of target, pointer size, and target size (Lopresti et al. 2008). In addition, adjustment may involve other physical characteristics of the control interface such as size (e.g., of trackball) and the grip of the device (e.g., of a joystick) or issues of functionality in control and configuration through connected software (e.g., see Oppenheim 2016). Along the same lines with pointing devices, configurations are necessary for the effective use of any other control interface, and they concern size and space, activation and selection methods, effort, flexibility, and sensory and cognitive characteristics, as well as sitting, position, and

coordination of the person in relation to position and mounting of the devices. For some control interfaces such as the eye-gaze technology, configurations can be complex and may require long-term piloting, training, and adaptations (Borgestig et al. 2016).

In a great number of cases of persons with physical disabilities, assistive technology for access is significant in determining technology for supporting other aspects of life, mainly communication. Hence, technology concerning augmentative and alternative communication (AAC) for persons with physical disabilities and complex communication needs is discussed in the following section.

Augmentative and Alternative Communication for People with Physical Disabilities

Augmentative and alternative communication (AAC) refers to a variety of techniques and tools, including no-tech (e.g., pictures and paper-based boards, signs, and gestures), low-tech (e.g., communication switches), and high-tech (e.g., digital devices) to help individuals with limited, not functional, or absent verbal communication/speech (ASHA 2018).

There are a great number of AAC techniques and devices that are available to individuals with complex communication needs, and most of them can be applicable for people with physical disabilities. Nevertheless, in physical disabilities, access, as discussed in the previous section, is a major parameter in the design and development of AAC interventions, as well as for the selection of relevant technology. Often AAC systems are categorized as follows:

(a) *No-tech AAC systems*, which include gestures, facial expressions, body movements, formal gestural codes, or manual sign systems (such as official sign languages). For physical disabilities, such systems can be applicable in cases where individual's physical condition allows for signing, gestures, and movement of any body part. In severe physical disabilities, the use of eye gaze for pointing (looking) at what is desired or responding to yes/no

questions is very common and often effective for basic needs.

(b) *Low-tech AAC systems*, which are usually divided in nonelectronic and electronic systems. *Nonelectronic systems* include cost-effective techniques that are easy to make or obtain, and they may be *letter/words/phrases or graphic symbol displays* organized either in sets of *individual cards, boards, mats, or grids or communication books*. These may also include formal communication systems such as PECS (Picture Exchange Communication System) (Bondy and Frost 2001). In most of these systems, communication is achieved by gaining attention of the communication partner with disabilities, who expresses him/herself by giving (e.g., a card), pointing at or looking at a symbol/sentence/word. In cases of severe physical disabilities, choice can be performed by eye gaze through *visual displays such as eye-com/e-tran frame boards* which include limited number of items on transparent boards facilitating the observation of the user's eye movement toward selection by the communication partner. *Electronic systems* are devices that permit the storage and retrieval of messages, many of which allow the use of speech output, and they operate with batteries. They are also referred to as mid-tech AAC systems. These may be *communication switches of a single, dual, or sequential recorded messages, devices of multiple recorded messages, and talking albums (photo albums with recording function)*. These devices differ in size, shape, number of visual items (e.g., pictures or symbols or even objects), and recordings they can hold, as well as in fixed or changeable display. Fixed displays hold the same number of items and recordings, while in changeable displays overlays, and sometimes number of items/options and recordings, can change. Similar to nonelectronic systems, the use of electronic systems by people with physical disabilities depends on features of access. A great number of electronic systems are designed in a way that allows alternative access for physical disabilities, such as switches (with or without

scanning mode), clearly separated and large cells, buttons, or ports for external access devices.

- (c) *High-tech AAC systems* are also electronic devices, which are based on computer and digital technology. They can be either dedicated devices (i.e., used only for communication) or non-dedicated which are computer-based (e.g., laptop computer, iPad, tablets), which are adapted for communication use, and which are used for other functions as well. High-tech AAC systems permit the storage and retrieval of messages and allow the use of speech output. They are often called speech-generating devices (SGDs) or voice output communication aids (VOCAs). With the advances of mainstream technology and the evolvement of mobile technology, non-dedicated AAC devices are becoming more and more popular. For people with physical disabilities, the use of high-tech AAC is closely related to features of human technology interface and interaction (HCI) and more specifically control interfaces. In the past there has been a long debate between dedicated versus non-dedicated devices and their flexibility according to the needs of individual potential users, with non-dedicated devices gaining more attention. Nevertheless, nowadays dedicated AAC devices mostly run on a Windows[®] platform, and therefore they are becoming more flexible, than in previous years, in terms of adaptations for alternative access (e.g., eye gaze, switch, head control) for people with physical disabilities, as well as convenient for people with less complex physical disabilities due to embedded accessibility. On the other hand, new tablet-style mobile technologies hold other advantages such as availability as mainstream technology, cost, and weight, but they are in many cases challenging for people with physical disabilities in terms of physical access options for adaptations (Abbott and McBride 2014) and external accessibility. Nevertheless, the use of mainstream non-dedicated (tablet-based or other) devices for AAC largely depends on the availability and flexibility of apps or

software, respectively, for communication. For physical disabilities, it is important that such apps and software also allow for the use of alternative access such as switch or eye gaze; hence this is not only a hardware issue.

A great amount of literature provides evidence on the potential of AAC for people with complex communication skills (Smith 2015; Calculator 2009; Lilienfeld and Alant 2005; Clarke and Kirton 2003), including people with physical disabilities (for instance, cerebral palsy, traumatic brain injury, neurodegenerative disabilities). On other hand, Light and Macnaughton (2014) argue that “despite the strong evidence of the benefits of AAC intervention, the potential of AAC remains unrealized for many individuals with complex communication needs” (p. 99). Individuals with physical disabilities and complex communication needs are often included in the number of people that do not benefit to the expected extent from the potentials of AAC, due to various factors relevant to personal characteristics (Smith 2015), training and digital literacy (Mavrou et al. 2017), professional support and follow-up (Mavrou 2011a), opportunities for participation, user’s own evaluation of technology function, and others (Huang et al. 2009). Hence, in following paragraphs the main characteristics and elements for successful AAC use for people with physical disabilities are discussed.

Feature matching between technology and the human/user needs, context, and activities is vital for the success of AAC in physical disabilities (and not only). To this end, input, processing, output, and other properties of technology need to be taken into consideration. Input relates to HCI and more specifically to control interface. Consequently, the use of AAC devices by users with physical disabilities requires physical skill development, whichever the selection method may be (Cook et al. 2008; Kay 2014). For physical disabilities physical skill development should specifically take into consideration not only functionality and motor constraints (Costigan and Newell 2009) but also safety and performance of the user, in order to experience success in communication efforts for developing AAC users’

self-esteem (Smith 2015). One of the key elements is reduction of physical effort, and this is why one of the breakthrough technologies currently widely used of access and communication for people with severe physical disabilities is eye-gaze technology (Borgestig et al. 2016; Light and Macnaughton 2014).

Processing is related mostly with communication competence development, not exclusively relevant to physical disabilities, but to all possible users of AAC. It is not connected solely to physical skills but also to selection sets, vocabulary, and language organization and development. Hence, issues of message/vocabulary retrieval, symbol set selection, messages coding (e.g., color or number coding), and location on device overlay are important. In addition, successful communication competence development also relates to communication partners' role and programs for language development (Smith 2015). Nevertheless, for physical disabilities, an individual may be a good communicator but a poor technology interface controller or vice versa. In such cases, the challenge is to design AAC user training programs that will address the user's profile for both access and communication (Costigan and Newell 2009).

AAC system output is also one of the features that should match user's need, activities, and context. Output issues involve visual, auditory, and maybe tactile modes of the message to be communicated, as well as issues of compatibility and interfacing with other assistive technology (e.g., power wheelchairs). Hence, in physical disabilities, decision on the output feature of an AAC system lies upon the sensory needs and abilities of the person; the context, environment, and activities she/he is involved; as well as the possibility of using other assistive technology. The latter leads to the last feature discussed here, referring to other properties relevant to physical disabilities such as portability, positioning and mounting of the device, customization, as well as training, support, and follow-up.

Bearing in mind the aforementioned, assessment and skills development for physical disabilities play an important role in effective implementation of assistive technology for access and communication. In the following section, the

main assessment and support in assistive technology models and methodologies are discussed.

Methodologies in Assessment and Implementation of Assistive Technology for People with Physical Disabilities

Assistive technology assessment is a dynamic process which is conducted utilizing a variety of methodologies usually not specific to one area of AT, the outcomes of which consist the guidelines for AT implementation and plan for monitoring and measuring the effectiveness of this implementation. A number of AT assessment models are described in literature. The various models differ in certain ways, but at the same time they share the main characteristics of the fundamental assessment process (CSUN Center on Disabilities 2006). This includes identification of needs (after the person's referral), identification of desired outcomes, assessment of skills and the trial of technology, revisit of outcomes, and repetition of the process in case they are not met or acquisition and implementation of AT in case desired outcomes are met, together with a follow-up and follow-along plan. Though, no model is specific to physical disabilities, some of the most widespread AT assessment frameworks are presented here, which are largely oriented on tasks and activities linked to (among others) physical activity. Nevertheless, it is noted that AT assessment and disability assessment in general have been discussed and criticized under the various perspectives and models of disabilities (Edyburn 2001; Hersh 2010; Kay 2014). This discussion is out of the purposes of the present entry, but it is acknowledged here that application of any assessment and AT implementation process should respect the social and human rights models of disability.

Human Activity Assistive Technology (HAAT) Framework

This framework is proposed by (Cook et al. 2008) "for understanding the place of assistive technology in the lives of person with disabilities, guiding both clinical applications and research investigations" (p. 36). HAAT was developed to analyze

the complexities of a person with a disability, performing an activity within a context, especially when the use of assistive technology is part of that context, and thus it has four components: the human (including physical, cognitive, and emotional elements), the activity (including self-care, productivity in all aspects, and leisure – taking into consideration the ICF model), the assistive technology, and the context (physical, social, cultural, institutional) in which the first three are integrated (Cook et al. 2008). According to Hersh (2010), in HAAT model, context is at the top with a hierarchical structure of the components, as context is considered a determining factor in whether the person (human) successfully uses AT to carry out an activity within it. Angelo (2000) argues that HAAT is widely used for emphasizing the importance of access methods, and thus it is very relevant for physical disabilities in relation to AT assessment and the identification of appropriate control interfaces and other access elements.

Students, Environments, Tasks, and Tools (SETT) Framework

The SETT framework was introduced by Joy Zabala and “is based on the premise that in order to develop an appropriate system of Tools [...] teams must first develop a shared understanding of the student, the customary environments in which the student spends time, and the tasks that are required for the student to be able to do in order to be an active participant in the teaching/learning process” (Zabala 2005, p. 1) (Joy Zabala, Sharing the SETT Framework, available at <http://www.joyzabala.com/>). The framework sets a series of questions in each of the four areas (students, environments, tasks, and tools) in order to facilitate communication and decision making, in systematic way (Edyburn 2001), and it focuses on the need for collaboration and communication among the members of multidisciplinary assessment teams. The SETT framework is not specific to physical disabilities, but it is broadly used for determining assistive technology tools for the needs of children with physical disabilities as it provides a very clear structure for identifying functional and other needs of the student, as well

as determining the specific tasks (Watts et al. 2004). Specificity of task is very important for choosing and using assistive technology (tools) for physical disabilities, as identifying (interface) control devices and selection sets and methods can differ for each individual with similar characteristics and tasks, which may be slightly diversified.

Matching Person and Technology (MPT) Framework

Matching person and technology (MPT) is a framework introduced by Marcia Scherer (1998), which focuses on three primary areas: (a) determination of the environment factors influencing use; (b) identification of consumer personal and psychosocial characteristics, needs, and preferences; and (c) description of the functions and features of the most desirable and appropriate technology (for more details, see Scherer 2004, 2005). The assessment protocols suggested by MPT were developed by collaborative and participatory research approaches, and they take a personal, collaborative (user and provider working together) approach to assessing the potential technology need. Hence, components are assessed in terms of their positive or negative influence on the technology use (Scherer et al. 2005; Scherer and Craddock 2002), in order to avoid technology determinism, i.e., considering the perfect technology (artifact) while disregarding personal and environmental characteristics, resulting in misuse or even abandonment of technology (Seymour 2005). Though, similar to the above models, MPT is not specific to physical disabilities, there is an amount of research on its implementation and further development, which is based on work with people with physical disabilities (see Scherer and Cushman 2000, 2001) often with complex access and communication needs (Borgestig et al. 2016; Smith and Connolly 2008; Kintsch and DePaula 2002).

Comprehensive Assistive Technology (CAT) Model

Responding to the need for a more comprehensive approach to assistive technology assessment and consideration, the CAT model, introduced by Hersh and Johnson (2008a, b), gives a more

inclusive perspective by defining all components of the *person* (social, attitudes, and characteristics), *the context* (social and cultural, national, local settings), *the technology* (activity specification, design issues, system technology issues, and end-user issues), and the *activities* (mobility, communication, cognitive, daily living, education and employment, recreation). CAT is closer to the approach of the HAAT model, as it holds a similar hierarchical structure of the human assistive technology system with the four main components at the top level of person or human, context, assistive technology, and activity (Hersh 2010). Again not specific to physical disabilities, CAT provides assistive technology and disability professionals the opportunity to consider examination of physical access for individuals with physical disabilities, from additional angles than the ones discussed above. Hence, complex physical needs and access are examined from the prism of not only the activity setting but also the social and cultural context. In addition, CAT draws the users' and the professionals' attention toward the use of new (mainstream) technologies and their embedded accessibility characteristics. It also extends the connection of (assistive) technology assessment in education beyond the physical educational environment adaptations to the pedagogy of diversity and disability for inclusive education.

The development of various different models of AT assessment (not limited to the above) highlights the multifaceted nature of the use of assistive technology (Edyburn 2001), which is even more prevalent in the case of persons with physical disabilities and more specifically when complex communication needs are present. In a certain extent, all models share similar foundation for exploring the person's needs and abilities, the environment, and the activities for which technology is required, and they also share the same ultimate goal: to identify the best technologies that will match the person's needs for improving the quality of life in all aspects. Similarities and differences of the models indicate the need for effective assistive technology assessment that will lead to the choice of technology that builds on the strengths of the person in their various environments and responds to challenges by

increasing opportunities. Hence, current literature calls for the need of a holistic assessment that at the same time can lead professionals involved to considerations beyond the sensorimotor and cognitive aspects of the access assessment toward language function and interaction (Kay 2014), as well as toward pedagogy and inclusion (Hersh 2010). Thus, collaboration, teamwork, and sharing of knowledge and experience in multidisciplinary teams (Copley and Ziviani 2005, 2007; Borgestig et al. 2013) are vital. This collaboration allows users', rehabilitation professionals', educators', and family's teams to get involved in dialogues (Watts et al. 2004) toward user-centered informed decisions in order to match the choice of both the model and the technology to the person's needs in all sectors of life and activity.

In the following section an example of a research case study of a person with physical disabilities and complex communication needs is briefly presented, demonstrating the implementation of the previously discussed technology features and models.

Example of a Research Case Study

This case study is part of a broader longitudinal qualitative research that involved several cases of persons with physical disabilities who use assistive technology (Mavrou 2011a). The present example describes the case study of a young man with cerebral palsy, during which data was collected through participatory observation, interviews, and document analysis in order to map assistive technology provisions and services in Cyprus and in attempt to understand, improve, and reform practice in relation to AT interventions. The participant is diagnosed with cerebral palsy (spastic quadriplegia), with no verbal communication and with no additional sensory or intellectual disabilities. Due to his physical disabilities and profound difficulties in verbal communication, he attended a special education unit in the mainstream school, in both primary and secondary education, until adolescence educators and professionals had difficulty to define his

intellectual and cognitive abilities. His communication was restricted to yes/no questions, to which he was responding with eyes and head movement.

The first assessment for assistive technology provision was conducted in lower secondary education. Following the basic principles of the SETT model (Zabala 2005), the first assessment identified the physical access to a digital communication device as the student's main functional area of concern, taking into consideration his age and interests; the need to move around in school environment with the aid of support staff (no electric wheelchair); and communication and participation in specific school curriculum subjects as the main tasks required for active involvement. Given the resources available at the time (in the public sector), a laptop computer with switch-accessible software (Clicker5) and a large-size switch with wireless adaptor were suggested as the main technology tools (Mavrou 2016).

Nevertheless, as the participant's communicative needs and abilities increased, the equipment proved ineffective. The use of the switch and scanning demanded increased physical effort by the user and entailed the risk of AT abandonment (Seymour 2005). Hence in 2 years' time, the AT specialist requested a reassessment, which was now conducted with mixed-models approach. These involved the basic principles of HAAT (Cook et al. 2008), especially for identifying the best approach to human device interaction, regarding physical accessibility, the pedagogical aspect of CAT (Hersh and Johnson 2008a, b) in order to match the needs of the participant in terms of inclusive education, and the MPT (Scherer 2005), to best determine environmental and other factors/barriers that affected the use of technology in various settings. Thus, a new long-term assessment process followed, which involved close collaboration and teamwork among the user, family members, the physiotherapist, the school technology teacher, and the assistive technology specialist. The ultimate goal identified was the use of high-tech AAC for the participant's independent communication and learning experiences, with a technology that would reduce the physical effort load needed. Thus, in terms of

control interface, the eye control (eye-gaze technology) was identified as the most appropriate for physical access, which is one of the reasons that long-term piloting, training, and adaptations were necessary (Borgestig et al. 2016). Eye control was considered to provide independence to the user for controlling his communication device, with direct selection as *selection method*. In addition, a grid-based augmentative and alternative communication software (The Grid 2) supported with Widgit symbols (localized in Greek) was chosen as a suitable *selection set*. Along with the matching of technology with the participant's needs and competencies, other configurations were made including sitting and position, mounting of the AAC device, and continuous adaptations of the selection set.

Following a collaborative consultation intervention model (Borgestig et al. 2013), the participant was able to develop excellent digital skills in very short time and to become a very effective eye-gaze user of his AAC device for both communication and access to digital technology (Mavrou 2016). In addition, in terms of selection set, he further moved from the use of symbol supported short phrases for AAC to independent symbolized phrases and words and then to gaining literacy and word prediction. Hence, the design of a customized language development program resulted in successful communication competence development (Smith 2015). In a short amount of time, the communication environment for this participant extended to the online environment and to the use of the Internet, email, Skype, and much more (Mavrou 2011b), leading to the integration of AAC out of a narrow set of contexts (Smith and Connolly 2008).

Though this case study resulted to a story of success, the whole process and intervention was long term, with a number of barriers in course and a number of difficulties that both the participant and the support team needed to overcome. These involved continuous access to technology during assessment and trials, funding, and resources that were not available on time, training of professionals and family members, as well as follow-up guidance and support (Mavrou 2011a).

Conclusion

The potentials of the rapid technological advances and the impact of assistive technology in the lives of people with disabilities are highly acknowledged and discussed in the relevant literature through the years (Abbott 2007; Hersh 2010; Borgestig et al. 2013; Mavrou et al. 2017). Research provides evidence for the role of technology, as well as the barriers and opportunities (Lazar and Jaeger 2011; Mavrou 2011a; Layton 2012) for its implementation in education and learning (e.g., Alper and Raharinirina 2006; Standen et al. 2011; O'Malley et al. 2013), in employment (e.g., Wehmeyer et al. 2006; Beyer 2012), in daily life activities (e.g., Schlieder et al. 2013), and in communication (e.g., Clarke and Kirton 2003; Light and Macnaughton 2014). Often, the design, development, and use of (assistive) technology for people with physical disabilities may encounter more challenges, particularly in the case of multiple disabilities with the combination of physical limitations and other sensory, cognitive, and/or communication difficulties (Veigl et al. 2017). A quite significant percentage of people with physical disabilities, especially those who are nonverbal, become less involved in activities, and they tend to have limited opportunities for interaction, learning, and participation (Mavrou 2011a; Angelo 2000; Borgestig et al. 2016).

While assistive technology can provide opportunities for independence, in order to increase motivation and activity involvement, for people with physical disabilities, there are a number of factors that affect AT's effective implementation. A holistic approach to AT assessment (Kay 2014) is important, which may derive elements from the principles of various different frameworks. When (complex) physical limitations are in place, the use of AT is highly determined by the way the dynamic interaction between the person, the technology, and the activity (Cook et al. 2008) is supported, improved, and sustained. Hence, the role of teamwork and multidisciplinary (Copley and Ziviani 2007; Borgestig et al. 2013), as well as the different perspectives that the various AT

frameworks provide for each of these elements (person, activity, environment, technology) (Watts et al. 2004), should go beyond the assessment process. Thus, collaborative and multi-dimensional approaches are fundamental for continuous access to AT tools, training, guidance, technical support, and mostly opportunities for implementation in multiple contexts.

It is evident that current and future research and development trends in technologies for people with physical disabilities have already turned toward user-centered designs and participatory action research (Dorrington et al. 2016; Veigl et al. 2017), as well as the investigation of the potentials of new mainstream technologies (e.g., mobile and Internet technologies) (Abbott and McBride 2014) and robotics (e.g., Cruz et al. 2017). Nevertheless, the collective effort for the successful implementation of technology for people with physical and other disabilities and the critical elaboration on research evidence should also be put forward by policy recommendations and policy making, with inputs from many high-level experts.

The use of assistive technology and accessibility is endorsed by the UN Convention for the Rights of People with Disabilities (Convention on the Rights of Persons with Disabilities (CRPD), available at: <https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html>). Hence, no state can disregard the importance of assistive technology service delivery systems in health, social care, and educational sectors. It is therefore suggested that future research should look into new ways of collaboration among all stakeholders at national and international level, including the industry, the academia, governments, as well as international alliances and umbrella associations (e.g., the EU, the UN, the WHO, etc.).

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Assisting People with Vision Impairments Through Technology

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Synonyms

Computer based and emerging technologies;
 Mobile; Ocular and cerebral vision impairment;
 Screen access; Wearable

Introduction

Over the past three decades, a great number of technological implications have been disseminated and applied toward communication, workplace, education, and life of individuals with vision impairment (i.e., those who are blind or have low vision). It is evident that many types of technology, such as assistive technology, augmentative technology, communication technologies, and/or alternative technologies, have influenced and enhanced the quality of life of people with vision impairment through supporting mobility, transport, health, and education (i.e., instructional practices and curricula). These technologies have contributed significantly to modifications of instructional methods and teaching strategies in the education of students with vision impairment (Gerber 2003).

In fact, technology and assistive devices allow individuals who are visually impaired to have access to a range of materials through a variety of different medium ranging from electronic to printed material. In our information-based society, this appears to be an unlimited capability and provides unprecedented educational and vocational opportunities for people with vision impairment (Cooper and Nichols 2007; Kerscher 2001).

Undoubtedly, assistive technology offers many advantages to people with vision impairment. Screen readers with speech outputs, optical character recognition devices, refreshable braille displays, electronic notetakers, and closed circuit television devices make feasible blind (or visually impaired) persons' accessibility to a vast amount and range of information (Cain and Merrill 2001). This new "era" was already been highlighted by the American Printing House for the Blind (APH 2008) mentioning in their annual report that assistive technology and its applications play a crucial role for 83.6% of students with vision impairment. According to the Individuals with Disabilities Education Act (IDEA):

"an assistive technology device refers to any item, piece of equipment, or product system, whether acquired commercially, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" whereas the term "assistive technology service is

defined as any service that directly assists an individual with a disability in the selection, acquisition, or use of an assistive technology device." (Luxton 1990; Parette and McMahan 2002; Presley and D'Andrea 2008)

Definition, Types, and Characteristics of Vision Impairment

Normal sight has a measure of 6/6 visual acuity on the Snellen test chart which consists of letters, numbers, or pictures arranged in rows of different sizes (Mason 1997). This though has now been overtaken by using the more accurate LogMAR scores (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2814576/>). Visual acuity also is represented as 20/20 or 60/60 (Snellen) or by 0.0 LogMAR. Thus, if a 6 m-size letter can be read at a distance of 6 m, the normal eye has an acuity of 6/6 or if a child has a visual acuity of 6/36 in one eye, it means that what a normal eye sees at 36 m, the person with the vision impairment could only see at 6 m.

This classification about the degrees of visual acuity was defined by the World Health Organization (WHO) and is widely accepted. According to WHO, children with a visual acuity of 6/18 to 3/60 are considered "partially sighted," and those whose visual acuity is less than 3/60 are considered "educationally blind." Another parameter, which is important regarding vision, is the ability to perceive objects distinctly at distance usually measured at 20 feet (distance vision, Scholl 1986). The Snellen test still remains one of the most common methods of assessing distance acuity internationally which consists of letters, numbers, or pictures arranged in rows of different sizes (Mason 1995). On the other hand, near vision acuity concerns types of close work. It is used in tasks such as reading, writing, and drawing. The procedure of testing near vision usually is associated with reading print of different sizes. Each print size is given an N number; the larger the number, the larger the print (Mason 1995). It expresses the ability to perceive distinctly objects at normal reading distance or about 14 inches from the eyes (Scholl 1986). This classification was significantly modified for the first time,

though not superseded, by a final draft of WHO (1999 version).

There are three main sites of the causes of vision impairment, which may result in a clinical acuity measure. For example, vision impairment may result from some form of ocular damage or damage to the optic nerve, and increasingly vision impairment may be as a result of damage to the brain visual pathway sometimes referred to as cerebral visual impairment (Lueck and Dutton 2015). All of these cases requires special educational arrangements (Mason 1997), but before examining the profile of children with vision impairments, there is need to ascertain what exactly it is meant by vision impairment and how it is measured. The term “visual acuity” was introduced by Donders in 1862 to describe “sharpness” of vision, although nowadays it is the ability to resolve fine detail and, specifically, to read small high contrast letters. Visual acuity is therefore the best direct vision that can be obtained, with appropriate spectacle correction if necessary, with each eye separately or with both eyes (Thomson 2005).

In a formal clinical setting, the standard measure of visual acuity is usually assessed through the “Snellen” notation. The “Snellen acuity” uses letter recognition on a Snellen vision chart. If another test is used to measure acuity, it will often have a Snellen equivalent since this is most easily interpreted vision scoring method.

The Snellen chart, although it is universally accepted, does have its flaws (McGraw et al. 1995). For example, the limited number of letters at the top of the chart does put people with very poor visual acuity at a disadvantage compared to those with better acuity. There is also the problem of irregular progression of letter sizes within the Snellen chart. The jump in difference between the letters representing acuities of 6/5 to 6/6 is an increase of 120%, whereas the difference from 6/36 to 6/60 is 167%. As Thomson (2005, p. 57) states “this is analogous to a ruler which is marked with different length graduations.”

Bailey and Lovie (1976) charts, which negated some of the disadvantages of the Snellen chart, are now being introduced. The Bailey-Lovie charts convert a geometric sequence of letter sizes to a linear scale and give a LogMAR notation of vision

loss. LogMAR vision testing offers a consistent and scientific method of recording vision scores. Although LogMAR is seen as the gold standard in measuring visual acuity, it is still common parlance to use the Snellen notation and to convert it using similar table. However due to the reasons just explained, these conversions are only approximate, and good practice dictates that comparisons between LogMAR and Snellen should not be made.

A more analytical spectrum in the classification of vision impairment is the WHO International Classification of Disease and Related Health Problems (ICD) Version 10 (2016) although as Ravenscroft 2017 has highlighted, cerebral visual impairment is not listed within ICD 10 coding system. In addition to the above classification, the element of visual functioning is equally highlighted by the Resolution of the International Council of Ophthalmology (<http://www.icoph.org/downloads/visualstandardsreport.pdf>) and the Recommendations of the WHO Consultation on “Development of Standards for Characterization of Vision and Visual Functioning (2003).”

It is interesting to present the recent key facts addressed by WHO (<http://www.who.int/mediacentre/factsheets/fs282/en/>) because it provides a global overview of the present situation regarding the population of individuals with vision impairments (VI).

- 285 million people are estimated to be visually impaired worldwide: 39 million are blind and 246 have low vision.
- About 90% of the world’s visually impaired live in low-income settings.
- 82% of people living with blindness are aged 50 and above.
- Globally, uncorrected refractive errors are the main cause of moderate and severe vision impairment; cataracts remain the leading cause of blindness in middle- and low-income countries.
- The number of people visually impaired from infectious diseases has reduced in the last 20 years according to global estimates work.
- 80% of all vision impairment can be prevented or cured (cited from <http://www.who.int/mediacentre/factsheets/fs282/en/>).

In conclusion, there are many differences among people who have severe VI. They are a heterogeneous group with a wide range of educational, developmental, and physical abilities and needs, which require specialized supports and services (Candlin 2003; Huebner 2000; Scholl 1986). The element of heterogeneity is reinforced by the fact that even when two individuals have exactly the same degree of vision loss, they may have tremendous differences because the way in which an individual uses whatever vision he or she has is unique (e.g., individual characteristics of people with vision impairment, vision loss, low vision, chronological age of visual loss). It is the so-called functional vision and plays crucial role in all aspects of life (Best 1992; Corn et al. 2000).

Assistive Technology and People with Vision Impairment: Challenging Limitations

When the person has a residual vision and can use his/her functional vision, then there are specifically designed technologies to meet the needs of those with vision impairment and maximize their residual vision. The vast majority of computers, for example, have accessibility features, such as magnification and speech output. Nowadays, many persons who have vision impairment (low vision) use computers, and they need a combined set of settings, devices, and software to facilitate their functional vision. For example, large monitors (21-inch screen) with accessibility features such as a built-in magnifier and contrast enhancement settings are common. Computer programs such as ZoomText can be downloaded to allow for an even greater range of magnification and contrast enhancement (http://www.aisquared.com/docs/zt2018/ZoomText_2018_User_Guide_English_UK.pdf).

The Multidimensional Function of Screen Access

Access to screen is made feasible through two different functions: (A) amplifying visual information through magnification and (B) translating

or transforming the visual information into alternative sensory information (sound such as speech outputs or touch such as braille).

High-Tech Optical Devices

Optical magnifiers have been the backbone of visual rehabilitation for many years and nowadays are enriched by high-technological optical devices bringing impressive outcomes regarding reading and clarity in image recognition (Virgili et al. 2013). There are near vision devices such as hand-held magnifiers and spectacle-mounted magnifiers. The baseline of these devices is usually twofold: (a) improved lighting and (b) contrast. On the other hand, there are the distance vision devices, such as handheld monoculars (one telescope) and bioptic telescope systems (two telescopes). The aforementioned implementations often include a zoom function, brightness and contrast controls, and color inversion. In essence, the above technological implementations fall under the umbrella of the computing process of magnification (Corn et al. 2000).

Closed Circuit Television (CCTV)

These devices, closed circuit television systems, are considered to be the “ancestors” of electronic magnification and contrast in the contemporary history of assistive technology for people who have residual vision. Two strands can be distinguished regarding these devices: (a) desktop CCTVs and (b) portable CCTVs.

Desktop CCTVs were the “groundbreakers” in electronic magnification and constitute the pillars for the systems that are used today. Flat screens are used, and apart from the traditional black and white contrast technologies, all up-to-date CCTVs have expanded this capacity into offering all the colors and saturations in order to design a great variety of contrast settings (Bennett 1997; Markowitz 2006). In addition, many models have cameras whose focus can be adapted for distance viewing and optical character recognition (OCR). These capacities enable the person with vision disability to read a page because the camera takes the photo, the OCR in turn converts the letters on the screen, and hence the user can read the page adjusting the magnification and contrast

or listen to a computerized voice that reads aloud text on the screen (Holbrook and Koenig 2000).

Portable CCTVs have the same properties as the desktop CCTVs plus the property of portability, which give users the freedom to travel or work away from their home desk system. Some of the more common units available are the Zoomax Snow and Zoomax HD 7, Pebble HD preis from Enhanced Vision, SmartLux Digital Portable Magnifier from Eschenbach, and Ruby from Freedom Scientific.

B. Translating or Transforming the Visual Information into Alternative Sensory Information.

This path of alternative sensory information needs at least two types of specialized software, which are usually embedded in computers, tablets, or smartphones. One is reading the text, namely, a screen reader, and the other one serves as a speech synthesizer. A screen reader “reads” what is displayed. In essence, a screen reader is software that is now commonly pre-installed in PCs, tablets, phones, etc., which reads aloud the text that appears on screen, such as documents, menus, icons, web pages, dialog boxes, phone numbers. The screen reader interprets the text on the screen (either on computer screen or on mobile phone) and uses electrical signals to activate the synthetic speech (Sherwin 2015). Through this software, people with vision impairment can access Internet resources, all texts contained in files, digital libraries, email, forums, etc. Some popular representatives regarding screen readers may be “JAWS” of Freedom Scientific (<http://www.freedomscientific.com/products/fs/jaws-product-page.asp>), “Windows Eyes” of GW Micro (<http://www.gwmicro.com/Window-Eyes/>), “SuperNova” of Dolphin (<http://www.yourdolphin.com/productdetail.asp?id=1>), or “VoiceOver” of Apple products (<http://macfortheblind.com/What-is-VoiceOver>) and the like. All the above apps or software provide speech output and screen magnification as well as refreshable braille displays can be connected and used.

The general term which encapsulates the process of transformation from visual format into aural format is called text-to-speech (TtS) technology (Dutoit 1997). Through this technology,

digital text is rendered aloud conveying all the meta-data of the text (i.e., lists, bold, italic, etc.; see Argyropoulos et al. 2015). The TtS can be used as stand-alone software, be built-in applications or operational systems, and be embedded in screen readers. TtS is much more effective than human narration, because the latter is time-consuming and requires much cost and effort (Peters and Bell 2007).

Sometimes the output may not only be speech but a tactile format such as a braille display. Through a specialized software, the system converts the content into braille characters. To transform the content into braille, an electronic refreshable braille display is needed which is hardware and is usually attached to the computer and driven by a specialized software. This particular braille display consists of a series of six- or eight-dot braille cells made up of small metal or plastic pins arranged in a rectangular context. The pins are raised and lowered depending on the electric signals, which are created due to the piezo effect of some crystals, whereby they expand when a voltage is applied to them. Each crystal is connected to a lever, which in turn raises the dot from a braille cell (Quick 2010).

Finally, the output may be a combination of tactile and aural stimuli. For example, technologies known as accessible pedestrian signals (APS) aim to assist people with vision impairment to cross streets through tactile arrows and audible signals. For example, poles with crosswalk buttons are placed within specified distances of the curb and crosswalk, and pushbuttons (the buttons used to request a walk signal) are placed on the side of the pole closest to the corresponding crosswalk (Carter et al. 2007).

Wearable Technological Devices

As mentioned above, the underpinning qualities that are essential for any technological implementation (software or hardware) regarding individuals with vision impairment are pertinent (a) to enhancing visual information via a variety of methods and techniques and (b) to transforming visual information into alternative sensory information, such as sound or touch. Another branch of assistive technology relevant to the above

qualities and related to ubiquitous computing (Velázquez 2010) is modern wearable technology. Wearable technological devices make technology pervasive by incorporating them into daily life. Devices worn on many parts of the body – such as the finger, hands, wrist, tongue, head, chest, abdomen, and feet – have been designed and tested over the last decades to provide wearable solutions to the problems of reading and mobility when it comes to navigation (i.e., indoors navigation, outdoors navigation) (Ramadhan 2018; Tsukada and Yasumrua 2004; Velazquez et al. 2009). In all the aforementioned devices, there are common patterns but differences as well. For example, outdoor navigational apps are usually designed differently than apps for navigation indoors because the former includes a GPS system, whereas this is not the case for the latter (indoor environments always change their reference points; therefore there have no stable structure over time).

Electronic eyeglasses constitute excellent example of wearable devices for improving vision (such as read books, distinguish street signs and objects from far away, and know what friends' and relatives' faces actually look like). Each of these electronic eyeglasses houses a high-speed, high-definition camera that captures what the user is looking at. The device through a series of algorithms enhances the video input and in turn displays the video through appropriate screens in front of the user's eyes (or even through auditory input). The cameras in real time enhance the footage that beams across two screens, one in front of each eye (Hwang and Peli 2014). In addition, a magnification process takes place combined with contrast. Lastly, as a wearable device, there is the capacity of a hands-free operation, which is of great importance for people who have significant vision loss, even up to 20/200 vision.

OrCam My Eye wearable technology, for example, constitutes an integrated portable device with smart camera reassigned to help individuals with vision impairment. The camera is attached to the glasses of the person who is visually impaired and transmits information converting the visual information into an auditory format in real time.

Labels, documents, banknotes, products, and other images, including faces and names, can be quickly and efficiently converted into spoken words. The device has multiple readable features that are compatible with headphones and speakers as well (<https://www.orcam.com/en/myeye2/>).

Mobile Technological Devices

Mobile assistive technologies constitute another platform for conveying and transforming information through accessible formats. Similarly, as it happens in wearable technological devices, smartphones and tablets – the main representatives of mobile assistive technologies – are now produced with accessibility options to allow magnification or contrast enhancement (Hakobyan et al. 2013). Many of the apps developed in mobile technological devices, which aim to support people with vision impairments fall roughly into three categories:

- (a) Navigation: Global Positioning Systems provide the person with vision impairment auditory instructions to streets and intersections, business names and addresses, public transportation or schedule appointments, and web searches (Chandana and Hemantha 2014).
- (b) Identification: specialized detectors provide the person with vision impairment feedback about the color of clothes, currency identification, products in supermarkets, and so on (Hild and Cheng 2014; Sangami et al. 2015).
- (c) Reading: text readers and barcode scanners provide the person with vision impairment audible formats or enhanced images (screen reader or screen magnification) to have access in large databases, such as national libraries, or in vast repository containing nearly every work of literature available in the public domain (such as the Project Gutenberg – Free ebooks, <http://www.gutenberg.org/>).

All the above share the same operation principle: they all scan the environment – using different technologies – and display the information gathered to other sense (mainly hearing and touch) (Velázquez 2010). Specifically, the

wearable systems are considered to be of high importance because they leave the users' hands free increasing in this way his/her degrees of independence and mobility.

Other Computer-Based Assistive Technology

Braille Embossers

These devices are hardware, which started to print text documents in the form of braille text. They use specialized software to convert text to braille. The evolution of the embossers continues to become more and more sophisticated, leading to new developed software applications, which in turn result in better-raised and recognizable dot tactile graphics. Nowadays, tactile graphics can be produced simultaneously with the braille text in the same hard copy sheet and by the same braille embosser (Kouroupetroglou et al. 2016).

Electronic Notetakers

Electronic notetakers are portable devices equipped with a speech synthesizer, a braille display, and a braille or typewriter keyboard. They are extremely useful in storing information, keeping track of appointments, and taking notes. They can be connected to braille or laser printers, and the latest electronic models of notetakers provide advanced word processing, web browsing, and other functions (Kapperman and Sticken 2000).

Specialized Keyboards

Users with vision impairment may benefit from keyboards with a high-contrast key legend or from the addition of high-contrast labels. Also, large key keyboards (with high-contrast lettering or color-coded keys) may enhance the residual vision of people with vision impairment and enable them to be efficient at work or at home (<https://www.techsilver.co.uk/large-print-keyboard-best/>).

Other Emerging Breakthrough Assistive Technology

In general, emerging technologies are characterized by radical novelty (i.e., have the capacity at least to challenge the status quo), relatively fast

growth, coherence, prominent impact, as well as uncertainty and ambiguity (Rotolo et al. 2015). Transforming emerging technology into assistive technology provision requires an ongoing effort, which includes collaboration with people with disability and discussing goals, needs, and functional links between capabilities offered by new technology and functional capacities of the person. One example of such innovative and breakthrough assistive technology for people with vision disability is the iBeacons protocols. These implementations constitute a special class of Bluetooth low energy devices that broadcast their identifier to nearby portable electronic devices. This technology enables smartphones, tablets, and other devices to perform actions when in close proximity to an iBeacon. Hence, people with vision disability through iBeacons can identify shelves in a supermarket, rooms in a campus or in a hotel, streets, areas, or points of interest (Stinson 2015).

Ultrasonic technological implementations in conjunction with Global Positioning Systems constitute up-to-date navigation systems where people with vision disability can detect obstacles and nearby vehicles, identify a place, provide information about traffic conditions and suggest alternative directions, monitor a direction, and/or cross-reference with other streets (Shahu and Shinko 2017).

In addition, high-tech learning spaces equipped with differentiated learning platforms seem to accommodate the changing dynamics of current education in order to meet at a global level all persons' educational needs including those who have vision impairments by appropriate hardware and software. The aim here is to promote web-accessibility and to provide differentiated e-content to learners with vision impairment and in the end enable them to learn and progress in an autonomous way (Kishore and Raghunath 2015; Ramakrishnan et al. 2017).

Finally, the use of robotics at the service of assisting people of vision impairment has been gaining ground in recent years. Indoor navigation involving multipurpose robots seems to prevail in human-robot interaction, and robot hardware

learning environment has already been embedded in educational practice and application (Marques et al. 2017).

This entry has not covered new technologies in bionic eye development, as while this could be seen as the latest advancement in assistive technology, it has been excluded as the technology is not yet available to all who need it while those described above are all available through the open market.

Conclusions

As mentioned above assistive technology, devices, and services have been developed to “increase, maintain, or improve functional capabilities of individuals.” In specific, there are different types of access such as the physical access, sensory, intellectual, emotional/attitudinal, financial, cultural, digital access, etc. (Dodd and Sandell 1998), and hence there are corresponding technological implementations which enhance and/or facilitate this accessibility. Regarding individuals with vision disability, all barriers have a common denominator (i.e., access to information in general) and significant differences as mentioned above about heterogeneity. For this reason, there is a big range of technological devices and services which are embedded in a bigger network including the person with the vision impairment (i.e., user), specific implementation(s) of relevant assistive technology, and the activity in conjunction with the environment in which it is being used (e.g., home, workplace, leisure).

Because of the universal design, there is a trend that the accessibility is not depended on the visual acuity of the person; rather the advances and all technological implementations are based on relatively new approaches and theories such as universal design or universal design for learning (Follette 2001). This means that the evolvement in technology resides more on a global basis of “thinking” and design rather than on specific needs. The needs of a person with vision impairment may change over time just as the site of vision impairment has, and as a consequence of this, a technological device should be adaptable,

up to date, and flexible to the person’s needs (Stephanidis et al. 1998).

People with vision impairment should be systematically trained in using assistive technology devices and software, by specialist professionals who have the expertise to properly exploit the technology (Guerette 2014). Furthermore, students/people must be assessed before trained in order to choose the assistive technology equipment that is suitable for them. The ultimate goal of assessment should be the selection of a device or equipment that meets the student’s needs. Technological advances should be conducive to blind students/peoples’ development, and assistive technology should be considered as an educational tool and not as an educational end (Abner and Lahm 2002). This is to say that assistive technology should be adapted in the schooling of students with vision impairments as indispensable means, promoting their literacy skills and enhancing their access to the full curriculum.

Anything that prevents or limits the inclusion and active participation of people with disabilities to social life constitute barriers. The accessibility of the common resources of the community (facilities, services and products related to housing, health and rehabilitation, education and vocational training, work, politics, sports) for the use of people with disabilities in conjunction to social awareness represents the essence of an open society (Male 2003; Ravenscroft 2016). The scope of the strategy sustains the increase of quality of life of people with disabilities in respect with independence, security, dignity, decision, and personal responsibility. With such advances in technology, people with disabilities – especially those with vision impairment – now have more options to visually enhance their daily lives and maintain independence.

Cross-References

- ▶ [Assistive Technology and Inclusion, Philosophical Foundation](#)
- ▶ [Games, Simulations, Immersive Environments, and Emerging Technologies](#)

- ▶ IT on Teaching and Learning Process of Visually Impaired Students
- ▶ Mobile Computing and Mobile Learning
- ▶ Mobile Learning
- ▶ Mobile Learning and Ubiquitous Learning

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Assisting Students with Attention Deficit Disorder Through Technology

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Synonyms

Computer-based instruction; Students with ADHD-related difficulties; Technology-aided attention training; Technology-aided self-regulation training

Introduction

Identified as the most common disability in childhood and adolescence, attention deficit hyperactivity disorder (ADHD) is characterized by developmentally inappropriate levels of inattention, impulsivity, and hyperactivity (Barkley 2014). The prevalence rates of this high-incidence and neurologically based disability range from 5% (APA 2013) to 11% (Ogg et al. 2015) with increasing rates being reported in recent years. The diagnostic criteria for ADHD involve persistent and severe difficulties in the aforementioned areas, the onset of which occurs in childhood and persists into adulthood (Steiner et al. 2011). However, variations exist with respect to the nature and severity of the difficulties experienced by young people with ADHD across developmental phases and also between sexes (Ogg et al. 2015).

Young people with ADHD often face functional limitations in their academic and social skills that cumulatively lead to diminished learning motivation, difficulties in completing academic work, and problems in developing positive interpersonal interactions with peers and adults (Barkley 2014; DuPaul et al. 2011; Lewandowski et al. 2016; Ogg et al. 2015; Polderman et al. 2010). Students with attention difficulties often encounter learning problems that hamper their academic progress and as such are more likely to be provided with special education services (Loe and Feldman 2007). These children are also more likely to terminate compulsory schooling early and not pursue post-secondary education (DuPaul and Weyandt 2009). Impaired inhibitory control has been suggested, in theory, to be a core deficit underlying ADHD and is associated with disruptive, off-task, and generally undesirable behavior (e.g., school rules infringements) that often warrants special attention and intervention by teachers (DuPaul et al. 2011). Thus, young people with ADHD are likely to display various emotional and behavioral difficulties (e.g., disobedience, aggressiveness, etc.) that adversely affect their interpersonal relationships and contribute to their social marginalization within schools.

School-based interventions targeting the learning and social needs of young people with ADHD are regarded as key primary support provision

(DuPaul et al. 2011) that fosters their educational and social inclusion in mainstream educational environments. A new era of technological development has opened up ways of providing education to students with ADHD which are expected to facilitate their learning, improve their academic and social performance, and promote their social inclusion in schools. Technological applications and devices have been found to be helpful in securing access to the mainstream curriculum and in accommodating the divergent learning needs of students' with ADHD within mainstream classrooms (Dolan et al. 2005). Digital devices, auxiliary computers, and electronic applications are beneficial for teachers, assisting them in the implementation of approaches tailored to the unique learning and social needs of students with ADHD, thus helping these students overcome the learning barriers they face (Schuck et al. 2016). More specifically, computers, various digital applications, and portable online devices have recently been identified as being promising in supporting the learning process of students with ADHD and facilitating in their training in the areas of attention and self-management skills.

Computer-assisted teaching provides students who experience attention-related problems with various alternative ways of accessing knowledge, which maximize their skills for the assimilation and generalization of new concepts. Accordingly, technology-aided learning can be useful in helping students monitor their attention and on-task behavior, thereby improving their overall academic performance as well as their social behavior in the classroom. However, computer-aided learning, technology-based attention, and self-regulation training used for teaching and assessing students with ADHD in a natural learning environment often produce mixed results, and hence further research is needed to clarify their effectiveness. These issues are briefly discussed below.

Computer-Assisted Instruction and Technology-Aided Learning

Over the past few decades, the use of computer devices, digital platforms, software applications, and hypermedia has proliferated, and they are

increasingly being used to provide learning support to students experiencing attention-related difficulties and ADHD (Fabio and Antonietti 2012; Ok and Kim 2017). Computer-aided teaching provides students with flexible interactive learning environments that enable them to highlight and summarize easily, access vocabulary, and test multiple ways of dealing with mathematical problems (Lewandowski et al. 2015, 2016). Despite its promising potential, research on computer-aided instruction for students with ADHD has been relatively limited (Lewandowski et al. 2016). Yet, the available data showing positive results is challenged by other existing studies that question the overall effectiveness of technology-based teaching for students with ADHD, making it difficult to develop a clear picture and draw conclusions. Therefore, further studies need to be carried out to substantiate the outcomes of technology-based teaching in specific academic areas and skills.

One of the strongest advantages of hypermedia tools is that they present learning concepts in a network structure and through a variety of perceptual channels, thereby facilitating access and encouraging assimilation (Mayer 2001). They facilitate the avoidance of distractions by presenting new concepts in such a way that relationships between these concepts are clearly demonstrated. They allow for increased incentive and learning as a result of the flexibility they provide in allowing students to access new ideas. As indicated in the findings of the experimental study conducted by Fabio and Antonietti (2012) on a sample of Italian adolescents with and without ADHD, the students facing attention problems were receptive and benefitted more when the teaching was presented in a hypertext format compared to conventional teaching. The data revealed that the participants who were exposed to the hypermedia-learning environment performed better in the acquisition and retention phases of learning than the control group. Their evidence is further endorsed by an earlier study demonstrating that computer-aided learning facilitates the development of new ideas and the creation

of links with pre-existing knowledge while minimizing the typical counterproductive behaviors of students with ADHD that undermine their learning outcomes (Solomonidou et al. 2004). Similarly, some other studies have found computer-based teaching to be effective for improving the learning skills and on-task behavior of students with ADHD (Mautone et al. 2005; Rueda et al. 2005; Shalev et al. 2007).

In spite of the positive results pointed out above, researchers highlight some methodological issues that raise concerns over the overall effectiveness of computer-based instruction. These issues are mainly related to the small sample sizes of available studies, the lack of control groups, and the limited sustainability of long-term effects (Lewandowski et al. 2016; Rabiner et al. 2010). For example, Rabiner and his associates (2010) conducted a randomized controlled trial research on the impact of computerized attention training and instruction on first grade American students with attention-related difficulties, including ADHD. Their intervention yielded positive outcomes on learning (e.g., reading fluency) and attention, as documented in the assessment conducted by class teachers. Nevertheless, the effects of the intervention program were of a modest magnitude, and attention improvements were not sustained in the following year. Thus, the researchers argued that interventions targeting the difficulties associated with attention and learning, which are experienced by students with ADHD, are in need of improvement, as is the method of evaluating the outcomes of such interventions.

In addition to the limitations highlighted above, the evidence available points to differential effects of computer-aided teaching on different curriculum subjects suggesting that ADHD students may be more likely to benefit from science and problem-solving teaching as opposed to reading (see for a review Lewandowski et al. 2016).

Some studies highlight the potentially positive results of available IT applications, mobile devices, and software targeting the learning difficulties related to ADHD and the improvement of

the academic skills and on-task behavior of students (Cullen et al. 2013; Mautone et al. 2005; Rabiner et al. 2010). More specifically, mobile devices (e.g., iPad, iPods) have recently gained prominence in education and have become popular tools used to enhance the learning experience of students with ADHD, mainly because of attractive and beneficial features such as touch screens, built-in cameras, Wi-Fi connections, and download capabilities. In today's world, an ever-increasing number of young people have access to mobile devices and are connected to the Internet (Common Sense Media 2011). Despite this, the use of such technology and its impact on students experiencing attention problems have not been thoroughly investigated by relevant research (Douglas et al. 2012). Indeed, available relevant studies often reveal mixed results in terms of the overall effectiveness of technology on improving and maintaining the academic skills of ADHD students (see Lewandowski et al. 2016). Within the context of the limitations outlined above, computer-based learning is anticipated to deliver a better outcome for students with ADHD if integrated as complementary training aimed at developing cognitive skills, such as attention, a skill that students with ADHD usually face major difficulties with.

Technology-Aided Attention Training

The rapidly evolving electronic world has encouraged the construction of various interactive computer-based games and applications that are easy to use and available to children and adolescents with ADHD (MeMotiva game 2013). These digitalized applications usually provide attractive virtual learning environments and platforms that integrate games targeting the development of various cognitive skills (De la Guia et al. 2015). Indeed, there are several digital computer-based game-type exercises available to young people with ADHD that aim to develop their attention, working memory, and task completion skills (e.g., *Home Routines*, *Attention Exercise*, *Play Attention*, *Cogmed*) (see [http://appcrawlr.com/ios-apps/best-apps-adult-](http://appcrawlr.com/ios-apps/best-apps-adult-adhd)

adhd and www.playattention.com and <https://www.cogmed.com>). Nonetheless, many of the available online applications and electronic game programs have not been tested yet, nor have their results been thoroughly evaluated (Lewandowski et al. 2016).

In addition to the abovementioned game programs, computer-based training focusing on attention skills is recommended for young people with ADHD as a means of improving their attention and further developing their thinking and problem-solving skills (Klingberg et al. 2002). Nevertheless, computer-assisted interventions targeting attention, and delivered to students with ADHD, have generally yielded mixed results in terms of their overall effectiveness and long-term sustainability. A case in point is that of Steiner and her associates (2011) who conducted a pilot study to test the results of a computer-based attention training intervention that was delivered to school-aged students with ADHD. Their sample consisted of 41 American middle school students with a formal diagnosis of ADHD and also included a control group. More specifically, of the 41 students participating in the study, 11 were included in the attention training program, with a further 15 serving as a control group and the rest receiving a different intervention. Their intervention program included sessions of auditory and visual exercises of increasing complexity targeting the students' impulsivity and their attention to the tasks presented. The study was carried out over a 4-month period. Once the participants demonstrated attention and achieved goals quickly, they received immediate feedback, and the accumulation of scores allowed them to move on to subsequent levels, which were more demanding. However, the data collected from teachers, parents, and students themselves showed mixed results. Although the parents of the participating students reported positive results regarding attention and other ADHD-related behaviors, their assessments were not consistent with those given by their children or their children's teachers, who did not detect any significant relevant improvements.

In another similar European study, De la Guia and her associates (2015) conducted experimental research to assess the outcomes of a novel interactive multi-device learning system based on a set of collaborative games and targeting the attention skills of young people with ADHD. Their sample comprised 12 Spanish children and adolescents with ADHD aged between 5 and 16 years who were receiving relevant support at a therapeutic clinic. The aforementioned system used software that controlled the interconnection and operation of various integrated computing devices (e.g., laptop, computer, tablet, mobile phone) allowing participants, who, without any prior knowledge of computer use, were able to interact by touching familiar objects. These interconnected devices were programmed to handle the input received from the participants and to indicate whether the task had been performed successfully. This attractive interactive platform encouraged students to develop ownership of the learning environment by manipulating a set of cards displaying images of animals. The participants were asked to indicate the correct set of images that appeared on the screen based on a growing level of difficulty. Once the embedded system reader had recognized the cards, it responded immediately, indicating whether the sequence presented by the students was correct. The evaluation results showed that the participants had demonstrated improved memory and attention and had enjoyed using the application. Nevertheless, as the researchers argue, the sustainability of the outcomes of this intervention and its applicability to larger samples, in particular, those in non-clinical educational settings, are certainly an issue that needs further examination.

As has already been mentioned, in addition to the significant difficulties experienced by young people with ADHD in the areas of academic and cognitive skills, their various counterproductive behaviors may place them at a high risk of social marginalization within education institutions. Consequently, technological applications and devices may be considered to be extremely promising tools in assisting young people to improve their social performance and mitigate the constraints they face in this area. Further, the combination of learning and self-regulatory

interventions is likely to contribute to the long-term maintenance of improvements in the academic and social behavior of the students (DuPaul et al. 2011).

Technology-Aided Self-Regulation Training

Self-management and self-monitoring programs have been among the most popular interventions for young people with various disabilities, including ADHD (Briesch and Chafouleas 2009; Reid et al. 2005). In contrast to the narrowly defined behaviorist approaches that are largely based on the external manipulation of the social environment, self-management programs focus on the learners themselves by encouraging them to monitor and evaluate their own learning and social behavior (DuPaul et al. 2011). Self-monitoring has been identified as a self-management strategy aimed at enhancing students' awareness of their own behavior through recording when a specific behavior has taken place. Typically, at regular intervals students report on their performance using a scale provided. Their teachers also complete a similar scale, and then the student concerned is reinforced depending on whether their assessments match those of the teachers' ratings (DuPaul et al. 2011). Some researchers comment on the positive outcomes of teaching meta-cognitive self-monitoring skills to young people with ADHD, mainly in promoting on-task behavior, academic completion, and work performance (Carter et al. 2011; Gureasko-Moore et al. 2007).

Various types of devices and online applications (e.g., iPod touch, iPad, smartphones) are considered useful in helping students with ADHD to self-monitor their attention and on-task behavior. However, their use in educational settings has not been systematically evaluated by research. Thus, despite the fact that some of the available studies show positive results (Laurice and Elisha 2011; Wills and Mason 2014), these positive effects may be of limited duration and may not be maintained when electronic devices are removed (see Lewandowski et al. 2016).

This is illustrated in the study carried out by Bruhn and her associates (2015). Experimental research was carried out by them to assess the

effects of an iPad application (SCORE IT) designed to assist two American middle school students (one with ADHD) to self-monitor learning as well as disruptive behaviors. This particular application stores the results of monitoring, carried out by the students and their teachers, in the form of scores based on the student's compliance with the rules of the class. These scores are then displayed in chart format at the end of each day. As soon as the participants' goals for each day are met, the students are reinforced by their teachers. The collected data can be stored and examined for up to five consecutive days, thereby allowing students and teachers time to review and track their progress. Although the results showed improvements in the participants' on-task behavior and engagement in learning, these were not sustained in the long run.

In line with the reasoning above, Schuck and her colleagues (2016) conducted a pilot study to test the feasibility of using a web-based application (iSelfControl) that was designed to evaluate student self-control and compliment traditional classroom behavior management approaches. More specifically, the pilot testing included 12 fifth grade American students with ADHD attending a clinical facility where a universal behavior management program had been implemented. Each student had their own iPad, and their application prompted them to evaluate their behavior every 30 min on three behavioral goals, namely, paying attention, following the rules, and behaving appropriately toward others. At the same time, teachers rated the students' behavior on another iPad. The application was designed in such a way that allowed staff to complete entries for many students within a very short time. The students could check their progress charts, on their iPads, throughout the day and receive feedback accordingly. This pilot intervention lasted for six consecutive weeks, and data collected consisted of a total of 141 teacher-student paired observations. The results indicated that by using this particular application, the students' awareness of their behavior improved, as did their ability to regulate their behavior effectively. Despite these positive outcomes, the researchers recommend that these results need to

be further substantiated by complementary studies involving larger samples of students and testing the iSelfControl in natural learning environments (e.g., classrooms).

Conclusions

This entry comments on the use of technology in assisting students with ADHD in their learning and in improving their on-task and social behaviors. In particular, we focused on technology-assisted instruction as well as attention and self-management training, which have been found to ameliorate the difficulties that this particular group of students faces in academic and social settings. Therefore, within this new evolving electronic era in education, computers, mobile devices, and digital platforms appear to be promising tools that may be used in promoting the academic and social skills and performances of students with ADHD. Despite their promising potential, however, we could argue that their application in natural learning environments and schools has not been thoroughly examined by relevant research in the field. Thus, some of the studies available suggest mixed results in terms of overall effectiveness, while others highlight methodological limitations that prevent researchers and practitioners from reaching clear-cut estimations and drawing conclusions.

Nevertheless, one of the strongest advantages of digital applications and electronic devices is that they can respond directly to the complex needs and interests of students and are therefore likely to contribute to providing specialized support within mainstream educational settings. Consequently, available evidence needs to be further substantiated by future studies that involve larger samples of students with ADHD as well as complementary data from natural educational environments, in addition to that collected in clinical settings. Educators and researchers need to work together on the implementation of technology-aided support interventions within mainstream classrooms. Teachers may need guidance from researchers and technology specialists to address the complex needs of ADHD students, as well as

receive training to successfully implement these promising technology-led educational support services.

Cross-References

► Teaching with Computing, Educational Games

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Assisting Students with Intellectual Disability Through Technology

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Synonyms

Assistive and instructional technology;
Intellectual disability

Introduction

Intellectual disability (ID) refers to limitations in intellectual functioning and adaptive behavior, with onset during the developmental period (AAIDD 2018; Papazoglou et al. 2014). Moreover, ID is characterized by heterogeneity in terms of etiology, and it pertains to a variety of behavioral profiles in terms of relative strengths and weaknesses through an array of domains including the cognitive, language, social, and socio-emotional domains (Bertelli et al. 2018).

Over the last decade, there has been an increasing emphasis on adaptive functioning and the consequent support needs of people with ID. In the latest (5th) edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association 2013), the severity of ID is specified on the basis of adaptive functioning which is considered indicative of the supports needed by a person with ID (Papazoglou et al. 2014). Even in earlier years, it became evident an increased emphasis on the development of individualized supports to address the unique needs of a person with ID within an inclusive environment, along with the development of relative measurement scales and tools (Thompson et al. 2009). This special emphasis was consistent with a turn toward the social-ecological model of disability (Shogren et al. 2017; World Health Organization 2001), while an even broader modus for viewing, understanding, and addressing intellectual disability has stemmed from the “social and human rights perspective” on disability (Bach 2017).

Within the context of such a broader perspective, a tendency toward more individualized or person-centered support services has been generated in pursuing the enhancement of inclusion and achievement without ignoring at the same time information on the unique challenges related to ID (Bach 2017). Furthermore, the concept of “support” is becoming the central part of interventions and policies that target the promotion of educational, social, community, work, and economic inclusion for people with ID. In this realm of “adequate supports” and “support services” to prevent marginalization and promote active

citizenship, quality of life and self-determination for people with ID, technology has been progressively recognized as a crucial enabler of these goals and of inclusion in general.

Connecting Technology with Support Provision and Inclusion

It is widely acknowledged that technological developments and resources have a catalytic role and effect in almost all aspects of our daily life. In light of this fact, the provision of opportunities for technology use by people with ID is a *sine qua non* situation in order for the modern societies to be considered inclusive; moreover, technology resources are among the critical supports for people with ID as they can assist them, under the appropriate conditions, in achieving independence, participation, and progress into inclusive societies.

In the context of providing personalized supports tailored to each person's with ID needs, strengths, choices, and goals, technology – in terms of devices, tools, systems, and solutions – (Lancioni 2017) can assist people with ID in improving their functioning in a variety of areas related to adaptive behavior, promoting their personal and interpersonal development, and enhancing their participation in school, work, leisure activities, and community (Wehmeyer et al. 2004). In other words and in light of a social-ecological point of view, technology, either instructional/educational or assistive, is considered a crucial part of the supports that should be provided to people with ID on the basis of their individual strengths and support needs to address the contextual/environmental challenges encountered within the school and the community in the course of their participation in inclusive settings in general (Thompson et al. 2016).

Today, there is an increased emphasis on inclusive education and in specific the inclusion of students with ID in general education classrooms (Thompson et al. 2016). Considering possible indicators of quality inclusive education, it has been suggested that they are related, among others, to the promotion of students with disabilities participation, progress, and achievement in

general education contexts and settings and to the implementation of curricula grounded in the principles of universal design for learning (UDL) (Loreman et al. 2014; Ryndak et al. 2014). Moreover, access to and availability of assistive technology are among the critical considerations relating to indicators for the measurement of progress in inclusive education (Loreman et al. 2014). In this vein, the provision of opportunities to use universally designed technology can facilitate all students, including those with ID, in meeting both the structured (i.e., academic) and informal (i.e., social) processes taking place into an inclusive school. Consequently, at the school level, technology could be conceptualized as a pivotal system of support for students with ID, in terms of enabling them through the pathway of their individual strengths to deal with an array of challenges in various key areas such as participation, independence, learning of new skills, academic achievement, and social functioning and inclusion.

A central issue in the process of assisting people with ID to increase their independence and foster inclusion through technology concerns the “means” by which the variety of available technological resources would be actually, purposefully, and fruitfully used by people with ID. This process of resolving the “what, how, and why” challenges – related to the application of technology to the field of ID – is translated into adequate interventions that enhance technology usability, as well as learning, motivation, and success by the students with ID (Lancioni 2017; Thompson et al. 2016). Selecting the appropriate technological solutions for a student with ID in light of a holistic understanding of the interaction between his/her strengths and weaknesses and the environment, without ignoring the user's opinion, and then teaching the student to effectively use these solutions consist important considerations in the process of bridging the gap that usually emerges between availability and actual and effective use of technological devices (Alper and Raharinirina 2006; Thompson et al. 2016; Zabala 2005). An actual turn toward the development of universally designed technological solutions is considered beneficial for all students with ID, and it could

result to positive outcomes in the areas of availability, utility, and usability (Wehmeyer et al. 2008).

Technology Use Benefits in Within-School and Out-of-School Contexts

In the relevant literature, technology use is characterized as instructional or assistive according to the particular purposes that it serves, although these two categories may have overlapping roles (Ayres et al. 2013; Thompson et al. 2016). Instructional technology refers to supporting students with ID toward their progress and skills enhancement in academic areas, and it applies, generally, in teaching of specific skills, while assistive technology aims at helping students to “participate in settings and activities in ways that they otherwise could not” (Thompson et al. 2016, p. 45).

Technology has become a key component of educational programs for all students and also a central consideration in the development of Individualized Education Programs for students with low-incidence disabilities (Lee et al. 2011). There are an increasing number of studies in the field of technology use by students with disabilities, indicating that both assistive and instructional technology solutions can be used in teaching students with ID and supporting them in various domains. Life skills, including daily living and social skills development, improvement of academic performance and engagement, enhancement of communication, and promotion of self-determined behavior, all of which can contribute to the educational, social, and community inclusion, are central to interventions involving technology use by students with ID. Moreover, positive outcomes for adults with ID in the area of employment-related skills and behaviors can be potentially achieved through interventions based on the use of technology devices (Wehmeyer et al. 2006). However, on the grounds of the heterogeneity issue in the field with ID along with the tendency toward the application of UDL principles, there are still suggestions for further

evaluation of educational interventions pertaining to technology use in relation to the abovementioned areas to strengthen their role as evidence-based practices (Bouck and Bone 2018; Wehmeyer et al. 2008).

The application of universal design (UD) principles in designing technology devices, along with an emphasis on cognitive access, can be beneficial for people with ID as regards the functional use of technology in a variety of domains and contexts (Wehmeyer et al. 2004). In their meta-analysis of single-subject design studies, Wehmeyer et al. (2008) examined the degree to which UD features, namely, “equitable use, flexible use, simple and intuitive use, perceptible information, tolerance for error, low physical/cognitive effort, size and space” (p. 23), were identified in the studies with regard to the technology device used. The results indicated that, with the exception of “flexible use,” every other UD feature was reported only in few studies (less than 10%). Nonetheless, it has been suggested that recent advances in the field of assistive technology, including mobile technology, are more likely to have the potential to meet the basic principles of UDL, i.e., “provide multiple means of representation, provide multiple means of engagement, and provide multiple means of action and expression” (Cumming and Draper Rodríguez 2017, p. 165). However, there is still a need for more research evidence with regard to the use of mobile technology in interventions to support students with disabilities across different areas (Cumming and Draper Rodríguez 2017).

Related literature includes numerous studies which demonstrate that educational software can assist students with ID in both academic and everyday skills. Moreover, recent tablet and smartphone devices offer a new user experience both through their mobility (in classroom-centered, outdoor, or home activities) and their multi-touch, direct manipulation interaction (Gunderson et al. 2017; Hetzroni and Banin 2017). This new user experience can have a direct effect on the acceptability and effectiveness of learning applications for students with ID.

With respect to research findings, assistive technology devices and in particular mobile

technology were found to have beneficial effects for students with ID in life skills development and consequently in the domain of independence (Ayres et al. 2013). It should be highlighted though that the notion of independence in relation to technology use can be viewed as a result of both skills (e.g., life skills) acquisition and reduction in external adult help during task completion. For example, in previous studies, self-prompting procedures with video, photographic, and auditory prompts using a personal digital assistant (PDA) were successfully implemented for the instruction of daily living skills, such as cooking and independent pedestrian travel, to high school students with ID (Mechling et al. 2010; Mechling and Seid 2011).

Taken an inclusive perspective, schools are to ensure meaningful opportunities for all students to learn and achieve (Florian et al. 2017). However, students with significant cognitive disabilities (e.g., moderate or severe intellectual disability) still face a high likelihood of placement in separate educational settings than in general, inclusive, education classrooms (Kleinert et al. 2015). Nonetheless, according to research findings, students with ID may have benefits not only in the social domain but also in academic learning within general education classrooms (Hudson et al. 2013). Technology has the potential to support students with ID on their performance, meaningful participation, and engagement in inclusive learning environments. For example, assistive technology solutions and especially the use of augmentative and alternative communication (AAC) systems (e.g., modern devices and applications based on tablet and mobile technologies) by students with ID having limitations in the area of communication are related to both within-school and out-of-school positive outcomes (Davies et al. 2018; Fossett and Mirenda 2007).

In respect of the provision of academic content instruction and the promotion of access to the general curriculum for students with disabilities, including ID, it has been suggested that the utility of advanced mobile technologies could enhance their academic achievement (Ok and Kim 2017). For example, Creech-Galloway et al. (2013) used

a simultaneous prompting procedure and delivered video via a tablet showing real-life situations with applications of the Pythagorean theorem to teach geometry skills to secondary students with ID and specifically the use of the Pythagorean theorem. Furthermore, technology (e.g., speech-to-text) has been utilized to academic skills instruction, such as writing skills, in students with ID (Cannella-Malone et al. 2015). Writing skills have been also taught in the context of promoting independence and functional skills. For example, the implementation of a computer-based instruction package in combination with a teacher-directed forward chaining procedure provided in a small group structure resulted in improved performance in manual spelling of grocery store words for students with ID attending a high school transition program (Purrazzella and Mechling 2013). In another study, written expression in the context of text messaging on a smartphone and in particular the inclusion of specific socially appropriate statements or phrases within text messages was successfully promoted in young adults with ID by involving a robot in the instructional procedure (Pennington et al. 2014).

The recent trend to extend mobile learning applications with augmented reality (AR) features offers additional opportunities for students with ID. AR has the potential to radically change the nature and effectiveness of digital learning material and activities, through a new 3D interactive experience (Reardon et al. 2016; McMahon et al. 2016). Another recent technological development with a clear potential to students with ID refers to educational robotics (ER), through their new interaction and communication capabilities and the facilitation of a stable environment for experimentation, creation, and learning.

To summarize, it is well documented that technology constitutes a promising avenue for supporting students with ID in educational contexts. However, taking into account the rapid advancements in technology, more empirical research evidence is needed on how and whether students and young adults with ID incorporate advanced technology into their lives (or have the opportunities to do so), across a range of contexts including academic tasks and learning, and

everyday living (home, interpersonal, leisure, and community activities).

In the relevant literature pertaining to technology use in people with disabilities, the potential role of technology on decreasing marginalization and assisting students with disabilities to enhance their autonomy is highlighted. In this case, a probably dynamic linkage between technology use and aspects of self-determination may be acknowledged (Ayres et al. 2013). Enabling a student with ID to effectively utilize technology either in academic or nonacademic contexts could have beneficial effects on student's self-determination. For example, previous intervention studies reported a positive impact of the use of microswitch technology on promoting communication skills in students with profound and multiple disabilities and specifically demonstration of responses related to access to preferred stimuli and choice making, both of which are considered aspects of self-determined behavior (Roche et al. 2015). Technology (multimedia) has been also used in promoting self-determination and self-advocacy in secondary students with intellectual and developmental disabilities in the context of enhancing their active participation in the Individualized Education Program and transition planning process (Van Laarhoven-Myers et al. 2016). Furthermore, the results of a previous study have also shown a positive effect on self-determination of an intervention involving technology use that aimed to promote the involvement of students with disabilities, including ID, in transition planning (Wehmeyer et al. 2011).

In light of the above, it could be suggested that technology has promising prospects for the improvement of people with ID functioning, participation, and progress in various domains, including education and everyday life activities. On the grounds of the implementation of inclusive practices, there is an increasing interest in developing strengths-based interventions targeting the effective and meaningful use of technology devices by people with ID on the one hand and on the other in successfully integrating instructional and assistive technology in education in order to promote positive school and post-school outcomes for students with ID.

Conclusions

Quality of life, self-determination, and social inclusion are among the prospective outcomes of supports provisioned for students with ID, and technology is considered as having a substantial role in the process toward their acquisition. However, a critical issue regards the students with ID sufficient training in using assistive technology devices in order to avoid its abandonment or low use (Alper and Raharirina 2006). Training and preparation of students with ID on the use of technology devices should be a substantial part of broader interventions targeting the organization of the decision-making process with regard to the selection of personalized technology supports (Ayres et al. 2013). The cognitive and adaptive behavior characteristics of students with ID and the related heterogeneity call for interdisciplinary teamwork involving the collaboration between experts in the field of ID, psychology, education and those with expertise on technical issues (Lancioni 2017; Wehmeyer et al. 2004). Nonetheless, the preferences of the students with ID should be a vital consideration during the development of assistive technology services and interventions (Taber-Doughty et al. 2008). On the other hand, rapid technological advancement induces a need for the school staff, practitioners, and professionals in the field of ID to pursue professional development on technology supports for people with ID (Ayres et al. 2013).

Technology seems to be quite promising in offering benefits to students with ID in terms of learning opportunities and educational and societal inclusion. However, there are critical challenges that need to be effectively addressed pertaining to the quality of technology supports, such as solutions tailored to individual needs and strengths in relation to environmental characteristics, and quality of technology usage, such as student's and teacher's knowledge, instruction, and positive experiences in using technology tools (Thompson et al. 2016).

Within an inclusive society, it is imperative to provide appropriate supports to people with ID to enhance their independence and quality of life, and within this context, technology constitutes a

promising pathway to this end. However, it is also imperative to assess and consider the experiences of people with ID by hearing their “voices” and asking for their opinion, besides preferences, on the perceived personal and social outcomes of technology use, and on the perceived parameters that could make more fruitful to themselves the use of technology and enhance their positive personal and social experiences as well (Tanis et al. 2012). Technology could be used as a vehicle for accomplishing such a perspective, since it may provide to people with ID opportunities not only to learn and achieve in a variety of fields but also to express themselves through various solutions.

Within inclusive settings, multimodal systems and material, including low- and high-tech solutions, should be available and used in combination with evidence-based instructional strategies to enhance active learning and engagement of students with ID in academic content (Hudson et al. 2013). The utility of advanced technology devices, especially mobile technology solutions (e.g., tablets), has opened new perspectives in supporting students with ID. The effective and appropriate use of mobile technology can be beneficial to students with ID in terms of educational, personal, and social goals and is considered a potential way of developing more inclusive classroom environments, promoting students’ participation, independence, and social interactions, increasing learning and self-expression opportunities, and decreasing stigmatization (Burke and Hughes 2018).

The utility of advanced technology on assisting and supporting students with ID is a rapidly evolving research area. Undoubtedly, the relevant findings can inform educational practice and intervention development efforts. In the current literature, a need for further research evidence to shed more light on several challenging issues is highlighted, such as the incorporation of assistive technology into classroom on the basis of UDL principles, the implementation of relevant strategies in inclusive rather than separate education environments, the development of evidence-based strategies and interventions concerning technology use, and the ways to facilitate the

utilization of technology by people with ID in terms of availability and usability (Bouck and Flanagan 2016; Cumming and Draper Rodríguez 2017; Ok and Kim 2017; Wehmeyer et al. 2008).

As discussed in the beginning of the entry, some of the key concepts behind the understanding of ID are *person-environment/context interaction*, *social and human rights perspective*, *social-ecological perspective*, and *strengths-based and personalized supports*. Information and communication technologies (ICT) and industry have identified the objectives of *adaptation* and *personalization* for their applications and services, as a means to meet the demand for a better user experience through technology. The e-learning industry has also adopted the “anyone, anytime, anyplace” motto, to underline the fact that barriers are increasingly overcome through the flexibility offered by technology. At the research level, personalized learning environments, which are capable to adapt to the profile of each individual learner, have been the focus for more than 50 years. The complexity of the problems involved limits the generalization and commercialization of respective results. Nevertheless, the emergence of the *ubiquitous* computing and learning era calls for more inclusive applications, to cater for the diversified usage scenarios of *all* users/students. In the knowledge society, users/learners are expected to access learning applications in different settings, which have profound effects on the understanding of disability. This fact has been acknowledged by the technical literature, as reflected in specifications of the IMS Global Learning Consortium (2004): “The term disability has been re-defined as a mismatch between the needs of the learner and the education offered. It is therefore not a personal trait but an artifact of the relationship between the learner and the learning environment or education delivery. Accessibility, given this re-definition, is the ability of the learning environment to adjust to the needs of all learners.” In this context, it can be expected that future learning applications and services will become progressively more inclusive to cover the needs of potentially *all* users/learners, including students with ID.

Cross-References

- [Assistive Technology and Inclusion, Philosophical Foundation](#)
- [Computer-Assisted Instruction, Changes in Educational Practice as a Result of Adoption of ICT](#)
- [Computer-Assisted Learning](#)
- [ICT-Based Inclusive Education](#)

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Assisting Students with Learning Disabilities Through Technology

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Synonyms

Actor-network theory; Education; ICT; Job opportunities; Learning difficulties; Learning disabilities; OECD; PISA; Social and collaborative technology; Special needs; Special needs students; Special schools; Students with learning difficulties

History and Definition of Learning Disabilities (LD)

The terms learning difficulties and learning disabilities are usually referred to as LD. The history of LD has been well documented with respect to the nature of particular problems (specific language and reading disorders and the behavioral correlates of brain injury) and the structure of special education at the time; a compelling case was made for the need for a category like LD (Kavale and Forness 1995). It should be noted that given the sensitive nature of this problem, and the wide range of special needs, one must be very careful when applying the definition as inferences could be drawn that could lead to negative results.

The history of LD in Australia has been documented in several studies, including Jenkinson (2007), Elkins (2000), and Rivalland (2000). In fact, the definition of LD that is adopted and accepted in a significant way in this important field is also debated, and according to this analysis, the definition hinges on the following main terms that are used in Australian schools:

- Learning difficulties
- Learning disabilities
- At educational risk
- Special needs

These terms are used to describe children who have difficulties with literacy and numeracy learning.

It should be clear to the reader that the meaning of these terms varies from state to state and from school to school in Australia. In fact, the author came face to face with the main actors of a special school where it was not the protocol to refer to students with learning difficulties as LD students, but instead, these students should be referred to by the term “special needs” students. Although these perceptions may be present, the term that has been universally adopted is LD as it is used globally and refers to students with learning disabilities; it should be noted that in the UK, the term Special Needs Education (SNE) is used

in a formal context to distinguish students with learning difficulties and other disabilities. In some publications, the term “learning disabilities” was used by the Department of Education, Employment Training and Youth Affairs (DETYA 1999) and was also used to classify funding categories for special needs students:

a student, who has been assessed by a person with a relevant qualification, as having intellectual, sensory, physical, social/emotional or multiple impairments to a degree that satisfies the criteria for enrolment in special education services provided by the government of the state or territory in which the student is located. (DETYA 1999, p. 2)

The definition of LD appears to be a little vague, and evidence from previous studies in the literature indicates that the normal mainstream curriculum appears to disadvantage this category of students. The question “What is LD?” has been a long-standing source of controversy, conflict, and crisis. Although research in LD has experienced unprecedented growth and has had significant impact on special education, it remains among the most problematic classifications because of the vagaries and antagonisms surrounding the definition (Shakespeare 2005).

Over time, a number of LD definitions have been proposed, but none had emerged as an unequivocal favorite. Currently the two definitions that dominated this area are the legislative definition found in the Individuals with Disabilities Education Act and the one proposed by the National Joint Committee on Learning Disabilities (NJCLD 1994), a consortium of representatives from organizations interested in LD.

The definition of learning disabilities (LD) is a very strongly debated matter. Organizations, such as the National Joint Committee on Learning Disabilities (NJCLD 1994) in the USA, and Australian government groups, such as MCEETYA (2005), have considered and debated the relevant definition of LD or special needs.

The definition of LD which has been adopted in this entry is the one presented by Kirk (1962) and is quoted here for completeness:

A learning disability refers to retardation, disorder, or delayed development in one or more of the processes of speech, language, reading, writing,

arithmetic or other school subjects resulting from a psychological handicap caused by a possible cerebral dysfunction and/or emotional or behavioural disturbances. It is not the result of mental retardation, sensory deprivation or cultural and instructional factors. (Kirk 1962, p. 263)

An issue that has concerned education authorities around the world is whether students with learning disabilities should receive their education in mainstream classrooms or in some form of special schools. A number of researchers support the view that students with LD require an alternative approach to their learning, while others claim that it is best to integrate these students with mainstream classes (Bulgren 1998; Kavale and Forness 1995). Overall, however, there is considerable evidence to support the existence of special schools to cater for the needs of LD students. These schools often exist on a small amount of funding support from the government; however, they cater for individual differences in a significant way through their own fundraising and budgeting efforts.

In a national Australian study that was conducted in 2000, it was found that particular schools demonstrated their comprehensive curriculum through the integration of ICT (Cormack et al. 2000). One of the schools included in that study was Concord School, Bundoora, Victoria; that school maintained its philosophy and belief that ICT provided a lifelong learning and skills for students with LD.

Early researchers concentrated on the learning difficulties of a single primary area or field like English, Mathematics, or Science. Their work and analysis depended on the identification of some criteria or factors like IQ, which did not adequately demonstrate the full scale of the learning problems and disabilities (Bulgren 1998).

From the early days of computers and technology, teachers and researchers were keen to explore computer-based tools in order to enhance learning outcomes. In particular, some of the computer-based software on dyslexia in the 1980s was developed by people who were closely related to students who suffered from dyslexia. For example, Stanovich (1980) used dyslexic software programs to aid students in this area.

It should be noted that similar software application programs were used in the UK and in particular people with dyslexia were assisted with ICT (Becta 2005). Other computer-based software involved mathematical problem-solving, games, and simulations. The latter is a significant area that involves ongoing research about the way games can stimulate and engage students with learning disabilities.

While these approaches may have provided an environment for work and stimulated the students' own interest, there was insufficient evidence to support that the learning outcomes had improved to a significant extent through these approaches (Newhouse et al. 2002 and Becta 2005). The entry will discuss and compare the participant observations from the special schools, and in particular, it will provide evidence of the impact that games have on self-esteem, engagement, and learning outcomes for LD students.

How Big Is It: Prevalence?

It should be noted that globally, the students with LD (OECD 2005) are a unit of interest for researchers, and in some cases, they appear as a sub-unit (subset) of a larger group of people who are disadvantaged in life – for example, the Australian Indigenous people, the Aborigines. In the UK, the House of Commons Education and Skills Committee, 2005, report summary states that:

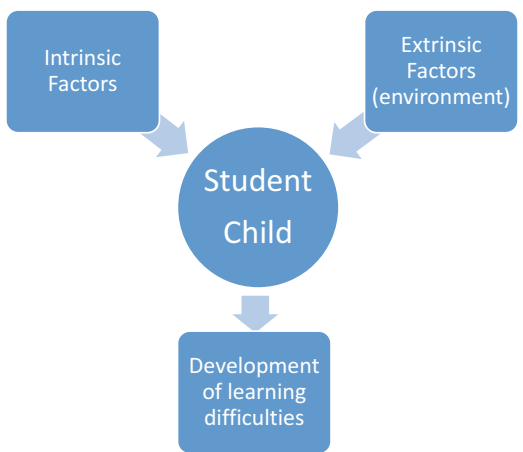
In 2005 around 18% of all pupils in school in England were categorised as having some sort of special educational need (SEN) (1.5 million children). Around 3% of all children (250,000) had a statement of SEN and around 1% of all children were in special schools (90,000)—which represents approximately one third of children with statements. With such a large number of children involved, it is important to recognise that many children are receiving the education they need in an appropriate setting. It is equally important, however, to highlight the difficulties faced by a large number of parents for whom the system is failing to meet the needs of their children. (HC: 478 I 2005-06, p. 5)

The Australian literature identified a study by Elkins (2000) where an analysis of learning difficulties and disabilities was reported (Fig. 1). The sections below provide a summary of the

main findings about this important area. The prevalence and identification or reference to special needs is also extracted from a study by Rivalland (2000) (Fig. 2).

The prevalence data were analyzed state by state in Australia in a study by Rivalland (2000) in “Policies and Practices: Students with Literacy Difficulties” case study in Elkins (2000) “Mapping the Territory” vol 1.

What is important here is quoted in the following paragraph from the report by Rivalland:



Assisting Students with Learning Disabilities Through Technology, Fig. 1 Learning difficulties: factors. (Source: Elkins 2000)

The many differences in definition and identification across the systems and sectors make it very difficult to make generalisations about prevalence. However, the case study schools do tend to reflect the findings of the Survey of Schools. Most of the case study schools, like the schools in the survey, reported a range between 10 percent and 30 percent. Many of the case study schools clustered between 15 percent and 25 percent with three schools reporting prevalence data below 15 percent. (Rivalland 2000, p. 51)

The terminology of learning difficulties and learning disabilities is further reflected in a survey (Rivalland 2000, p. 69) where principals referred to these categories by the following percentages listed in Table 1.

The term “learning disabilities” was more likely to be used by teachers with special education training and by school psychologists. The term LD is widely accepted in the psychological field in the USA, but is usually qualified in Australia to specific learning needs.

The definition that has been used for the term LD by MCEETYA (1999) is similar to one from the USA and is provided here to assist the discussion:

A generic term that refers to a heterogeneous group of students who have significant difficulties in the acquisition of literacy and numeracy and who are not covered in the Commonwealth’s definition of a student/child with a disability. . . Learning disability is believed to be a difficulty that is intrinsic to the individual and not a direct result of other conditions or influences. (MCEETYA 1999)

Western Australia	Victoria	New South Wales	South Australia	Queensland
Crestwood (20%)	St Bernadette’s (5%)	Lake Hewitt (25%) estimated by principal	Messiah (13%)	Bennetts Hill (24–25%)
Rivergums (30%)	Hilltop (10–20%)	Grisham (15%)	Franklin Landing (15%)	Durie (25%)
St George’s (22%)	Mountain Ash (10–15%)	ST Philomena (15%)	Beachcliff (17%)	St Evangeline (32%)
District High (10%)	In Victoria, very high estimate of at risk students were shown at the start of Year 1			Thornburn not applicable Learning disability program

Assisting Students with Learning Disabilities Through Technology, Fig. 2 Prevalence data. (Source: Rivalland 2000)

Assisting Students with Learning Disabilities Through Technology, Table 1 Reference to learning difficulties. (Source: Rivalland 2000)

Factor	%
Learning difficulties	47
Children at risk	37
Special needs	17
Learning disabilities	10



Assisting Students with Learning Disabilities Through Technology, Fig. 3 Venn diagram for learning difficulties

Range of Special Needs

Given the complexity of the definition of learning difficulties, one way to represent these differences is with the following Venn diagram shown in Fig. 3.

The term “learning difficulties” is used to refer to a large group of children who need extra assistance with schooling, while “learning disabilities” refers to students who are a small sub-group who exhibit severe and unexplained problems. In fact, in the USA, it is also referred to as “learning educational disabilities.”

The research presented here originated with an interest in dyslexic students. A federal government report on students with disabilities – “Technology for Learning: Students with Disabilities” – reported 21% prevalence (Cormack et al. 2000). In a study by Miles (2004) in the UK, a number of issues were discussed that might account for the difficulty of assessing the prevalence rate with dyslexia around the world. Among these are the issue of resources to carry out the analysis and dyslexia variants. The prevalence rate varies between 5% and 17% (Wikipedia), and Miles (2004) arrived at the conclusion that

in the UK, there are approximately 4–6% people who are dyslexic. All that can be said with any certainty is that in every English-speaking country, a significant percentage of the population has reading and spelling difficulties varying from mild through to severe. A parliamentary report titled “Helping People with Dyslexia: A National Action Agenda” shows that the prevalence rate across all states in Australia ranged from 5% to 10%. These facts show that the prevalence rate of dyslexia has not changed by a significant amount over the last two to three decades.

Models for Education and Technology for Disability

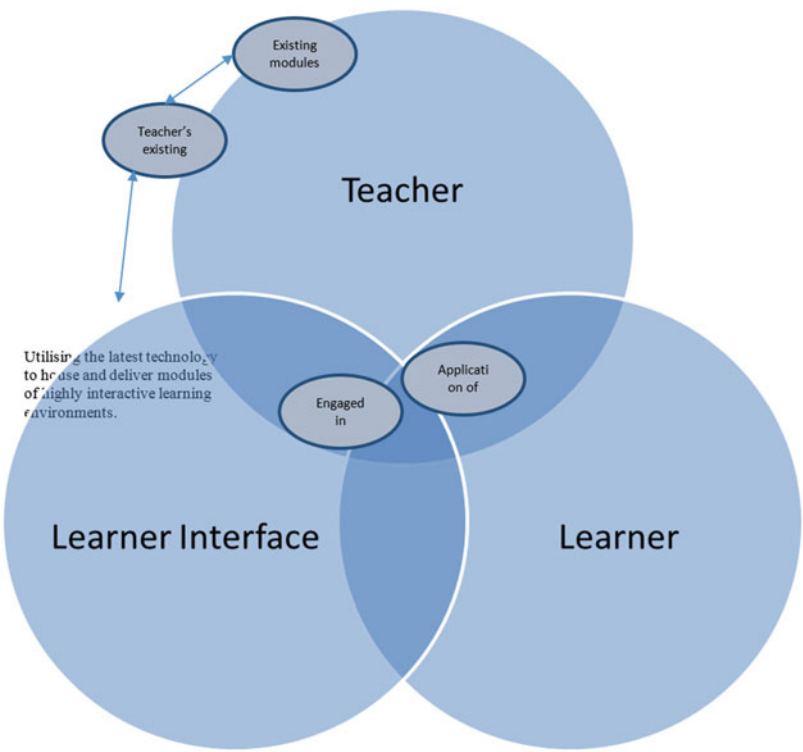
A starting point in modelling learning with ICT is the Learning Interface Model (Adam et al. 2006) – see Fig. 4. In this model, teaching can be thought of as an interaction between teachers, students, experience, and knowledge (Schunck and Nielsson 2001). How these entities interact can be seen in different teaching/learning paradigms, ranging from one characterized by a verbal flow of information streaming from the teacher directly to the students to the model shown in Fig. 5.

In this model, the teacher acts as a catalyst or consultant for students to show them where information can be obtained from. Next, we can consider the model from Schunck and Nielsson (2001) as a starting point to examine what changes are needed to the traditional teaching model as we move toward the adoption of technologies in the curriculum. These changes are captured in Fig. 6; this is a reproduction of the model in a study reported by Schunck and Nielsson (2001).

From Traditional Teaching and Learning Models to e-Learning

In their study, Schunck and Nielsson (2001) examined three different scenarios to describe pedagogic developments from a historical perspective. These perspectives primarily focused upon the interaction between teachers, students, and given subject matters (domains). In proposing

Assisting Students with Learning Disabilities Through Technology, Fig. 4 Learner Interface Framework – Adapted from Brusilovsky and Papert. (Source: IEFTS 2001)



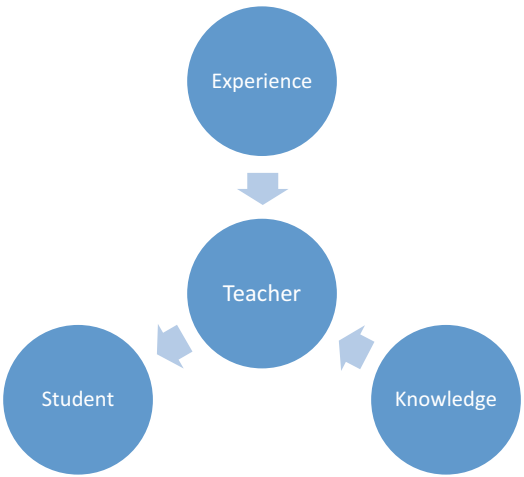
their model, they considered the following paradigms:

- The paradigm of yesterday*
- The paradigm of today*
- The paradigm of tomorrow*

Naturally, the structure and the developments in the surrounding society as well as the political dimensions play an important role as far as the models' individual lifetime and the transition from one model to another are concerned. The models may be looked upon as changes of paradigms, assuming new forms in connection with the implementation of new discoveries or theories and new decisions or changes in views and attitudes.

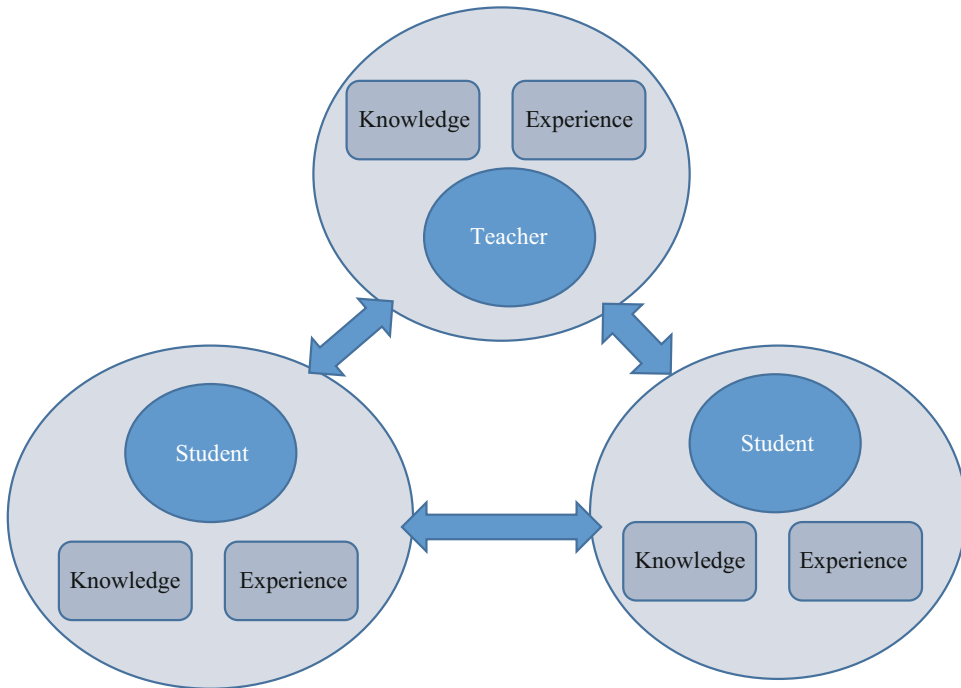
Adopting the Schunck and Nielsson e-Learning Model for LD Students

The study adopted the above e-learning paradigm to determine the impact of technology on the educational outcomes of LD students. The model



Assisting Students with Learning Disabilities Through Technology, Fig. 5 Paradigm of yesterday. (Source: Schunck and Nielsson 2001)

in Fig. 7 illustrates the facilitating role of the teacher and the independence of students in working and sharing their knowledge through experiential learning. The early research was



Assisting Students with Learning Disabilities Through Technology, Fig. 6 Paradigm of today. (Source: Schunck and Nielsson 2001)

proposed at Macedon Ranges where this model was applied to the main actors, like the school principal and the IT coordinator. Fortunately, the model was accepted, and the research study was facilitated through the exploration of the policies and infrastructure that was available at the school level.

Technology Enablers and Inhibitors for Disability

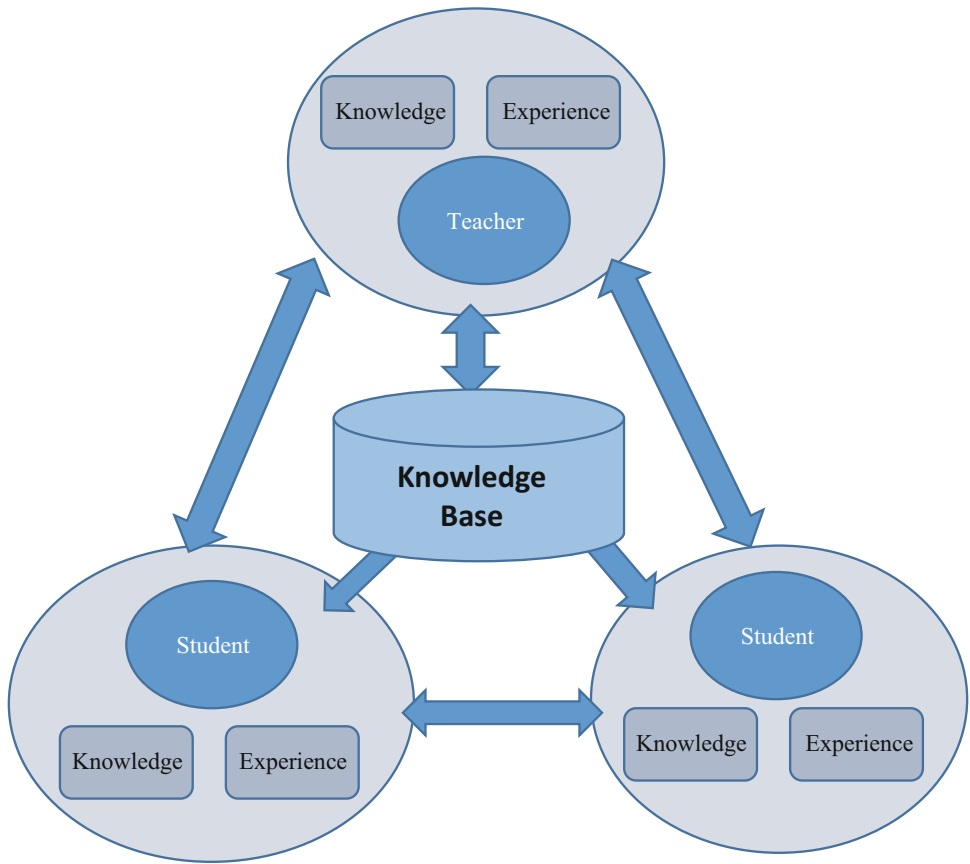
Earlier research explored issues regarding both the adoption and impact of ICT in teaching and learning. The main regions that were considered were Australia, the UK, the USA, and Africa. In addition, studies were found from some other countries like Turkey, Nepal, and Malaysia, where technological, political, and socio-technical factors were investigated. The main findings from these studies relate to school leadership, professional development, and perceptions from

parents. In a study by Elliott (2005), the main factors that were identified were in fact divided into two categories, structural and process barriers, and are summarized in Tables 2 and 3.

According to Elliott (2005):

ICTs have not had the widespread impact on teaching and learning processes envisaged a decade or so ago is disappointing but not surprising. Most educational innovation happens slowly and ICT is in itself continually transformed by new developments and market conditions. It is not a discrete subject and its applications in education are the subject of considerable debate, informed by a combination of scholarly discourse, opinion and research. (Elliott 2005, p. 8)

Elliott further provides a summary of the literature for barriers to effective ICT learning in schools. The following are highlighted in several contexts (White 2005), and calls for national ICT standards, greater institutional support and infrastructure, and better professional development for teachers have been addressed to varying degrees in all states and territories.



Assisting Students with Learning Disabilities Through Technology, Fig. 7 Paradigm of tomorrow: the e-learning paradigm. (Source: Schunck and Nielsson 2001)

Assisting Students with Learning Disabilities Through Technology, Table 2 Structural barriers for ICT adoption. (Source: Elliott 2005)

Structural barriers
Limited classroom space
Lack of computers and/or internet in classrooms
Unreliability of the technology
Lack of leadership and support from principals
Lack of institutional support and encouragement
Poor technology infrastructure
Class timetabling difficulties, short lessons

Elliott further proposed the following factors should be considered for the adoption of ICT in schools: school leadership, teacher competency, level of support, teachers of LD and ICT ongoing,

Assisting Students with Learning Disabilities Through Technology, Table 3 Process barriers for ICT adoption. (Source: Elliott 2005)

Process barriers	
Poor teacher attitudes toward technology, lack of teacher confidence	Lack of professional development or inappropriate PD
Conflicting information on the value of ICTs in learning	Lack of time for planning and preparation
Limited teacher skills and competence especially in the face of rapidly changing technology	Lack of involvement in computer room and/or classroom layout/planning
Classroom management difficulties	
Difficulty to adjusting to new pedagogies	

teacher awareness, and teachers' view of ICT (Soderstrom 2009).

In a study by Bates et al. (2007), models of early adoption of ICT innovation in education were considered. In particular, the characteristics of early adopters were reviewed, and these basically related to the following main areas:

- Experienced microcomputer users
- Individuals displaying opinion leadership qualities
- Individuals more likely to investigate new developments

Elliott (2005) further argued that in order for technology to be accepted and incorporated in learning and communication, the following three main areas must be considered:

1. Encouragement of teachers to embrace ICT in their teaching and school culture.
2. Investigation of how ICT can best support and improve the learning outcomes.
3. Analysis of the impact of the digital divide.

In general, Australian teachers felt that they did not have adequate support for effective ICT use and integration of ICT in the curriculum. This view was also supported in research studies by Becta (2005). Moreover, research studies by OECD (2005) and Meiers (2009) provided similar arguments and concerns from the teachers.

Environment for Technological Innovation

National and other studies on the use of technology by Newhouse et al. (2002), Shaddock (2007), Meiers (2009), and White (2005) established that ICT has a positive effect on teaching and learning. In the UK, Becta carried out several research studies to determine the impact and adoption of ICT in schools.

The movement and acceptance by schools of technology is summarized by Ertmer et al. (1999):

Despite the fact the number of the computers in teacher's classrooms has increased dramatically in the last 20 years, researchers and educators alike report that integrating technology into classroom curricular is not easily accomplished. (Ertmer et al. 1999, p. 54)

Undoubtedly, technology has been adopted and integrated successfully in the administration of schools. In Victoria, for example, this was promoted and progressively rolled out through policy initiatives between 2000 and 2006. The aim is to provide a standardized platform for Victorian government schools in order to help them manage their core administrative and finance functions. The software, called Computerised Administrative System Environment in Schools (CASES21), is an integrated school administration and finance system that supports approximately 1600 government schools. It is designed to facilitate schools with data reporting to the Department of Education and Early Childhood Development (DEECD). Although the Auditor General's 2008 Report findings show that the system has improved school administration for a broad range of schools, there are a number of large schools that have reported that the perceived benefits have not yet been fully achieved (Auditor General's Report 2008, CASES21 2008).

A report by Cuttance on school innovation concluded that school classrooms were adapting to the needs of students so that they can develop skills and knowledge to use information, to collaborate, and to communicate effectively with others through ICT (Cuttance 2001). The report further stated that there is no unequivocal evidence about the impact of ICT on the learning outcomes of students although a significant number of studies had indicated that there is potential for ICT to improve the learning outcomes.

In addition, similar to the findings from Becta (2005), the report supports the view that computers in classrooms increase student motivation and increase student control over learning and access to information (Shaddock 2007; Meiers 2009).

The last example to innovations and projects in this section is the Innovation and Best Practice Project (IBPP) from the Cuttance (2001) report. The report included a study on the impact of laptops with 20 schools in the special project (IBPP). For one of the groups where the students had their own laptop, the research evaluation for the innovation program did not produce evidence of their impact to be as strong as the group that used desktop computers. The innovations were based on constructivist learning principles because contemporary learning theorists argued that this was the most appropriate way to facilitate the students learning outcomes and allowed them to control their progress in ICT integrated classrooms (Shaddock 2007, and Cuttance 2001).

The Value of Using ICT in the Education of School Students with Learning Difficulties

Children with Learning Difficulties

The Good Schools Guide (2016) points out that: “Some students who have no obvious physical or mental impairment can have trouble managing tasks necessary for learning, such as concentrating, keeping still, making themselves clear or understanding tasks set in class.” The term “learning difficulties” (LD) is used to refer to this quite large group of children who need extra assistance with schooling that arise from a vast range of cognitive and physical impairments.

Several related terms are “special needs students,” “students at educational risk,” and “students with specific learning disabilities.” While the terms “special needs students” and “students at educational risk” mean essentially the same as “students with learning difficulties,” the term “specific learning disability” refers to a distinct handicapping condition for a small sub-group of students who exhibit severe and unexplained problems. In this entry we will refer only to “students with learning difficulties.”

Learning Difficulties Australia (LDA 2016) notes that in Australia, the term learning

difficulty refers to those students “who experience significant difficulties in learning and making progress in school, but who do not have a documented disability such as an intellectual disability” and that about 20% of students (LDA 2016) have some form of learning difficulty in some aspect of learning. Most schools are able to help these students in some way by setting up special classes, by working with teachers and parents to help them in ways of coping, or by the use of specialists. In other cases special schools offering greater support and a specialized learning environment exist to cater for these students.

Many countries have tackled the dilemma of school membership for students with learning difficulties considering whether these students should be kept in mainstream schools or moved into special schools designed to cater for their needs (Adam et al. 2006; Laabidi et al. 2014). Although many researchers claim that it is best to integrate these students into classes within mainstream schools, numerous “integration” or “remedial” programs in mainstream schools have proved ineffective for the total learning of this group of students. There is strong evidence to support the existence of segregated special schools, and there are around 35 special needs schools in metropolitan Melbourne (Australian Schools Directory 2016). Many previous studies on LD have focused on only one or two specific factors such as IQ, but the literature shows that IQ does not yield valid results or assessments here. The literature also provides examples of where these students in normal classroom settings achieve little success in situations where technology was not regarded as an integral part of the curriculum (Meiers 2009).

The research underpinning this entry was primarily undertaken in two special schools in metropolitan Melbourne, Sunbury and Macedon Ranges Specialist School and Concord School, concentrating on their use of ICT and computers in classrooms. Discussions were also held with two local polytechnics and an industry training organization on the possible further education of these students.

The study reported here was highly motivated due to work with students with learning difficulties over a long spanning teaching career. Special school programs were coordinated such as the school's federal government funding for special schools program (DSP). This program was set up for the allocation of resources for students with special needs in the 1980s. This interest and motivation culminated in the present research study. It led to the close participation and observation of students with special needs in two outer suburban (regional) special schools (Macedon Ranges and Concord) and, in addition, an individual case study to apply some of the early findings and make a comparison. One of these schools provided a basic ICT infrastructure for its staff and students, while the other provided a more enhanced "state-of-the-art" ICT environment that was integrated into the school's curriculum.

These two schools provided two distinct geographical groups of students and were observed over a significant time period. During this time various government departments and agencies were also visited so as to gain an insight into the level of ICT support for students with learning disabilities (or special needs). These included Technical and Further Education (TAFE), the Royal Children's Hospital (RCH), and also some private individual consultants. These consultants worked with a significant group of LD students on a regular basis on language skills and speech pathology at RCH.

In closing this section it should be observed that an investigation on the infrastructure provided a strong link with the Department's IT services. This link enabled the study to determine the level of support that existed for school projects including those that involved ICT with video-conferencing. Furthermore, the Department provided the necessary support for the investigation and analysis of the infrastructure; indeed, this support was essential for setting up the link between the special schools through the Local Area Network (LAN) of the Department.

Methodology

This research was qualitative, framed by actor-network theory, and involved case studies at two special schools in suburban Melbourne over several years by one of the authors who attended and observed specific classes at these schools on a regular basis. Due to the sensitive nature of this area, special approval needed to be obtained from the Victorian Education Department. This allowed a single researcher to enter and observe activities in the school classrooms. The case study data described in this entry was collected mainly between 2003 and 2008 (Adam and Tatnall 2012) and consisted of interviews with the school principal, teachers, and parents (Adam 2011; Adam and Tatnall 2014) on student learning, attitudes to learning, and overall progress. (School pupils could not be formally interviewed under Education Department ethics rules, although informal discussions with some students were held.) As this was exploratory research and the data sample was not large, no claim was made to the generalizability of the findings although it was suspected that further research would confirm them.

Special schools are especially complex socio-technical entities, and research into their infrastructure, organization, and curriculum needs to take account of this complexity. A significant difficulty arises in framing research in a situation like this that involves both technological and human actors ranging from students and teachers to software and broadband connections. When dealing with the related contributions of both human and non-human actors, actor-network theory (Callon 1986) provides a useful framework. Actor-network theory (ANT), or the "sociology of translations," is concerned with studying the mechanics of power as this occurs through the construction and maintenance of networks made up of both human and non-human actors. It attempts to allow for the socio-technical nature of research of this type by giving due and equal treatment to the interactions of both the human and the non-human actors that are involved in each situation and to deny that in regard to technological innovation, purely social

or purely technical actions are possible. ANT reacts against the idea that characteristics of humans and social organizations exist which distinguish actions from the inanimate behavior of technological and natural objects, instead offering a socio-technical approach in which neither social nor technical positions are privileged (Adam and Tatnall 2012).

The actors involved in the adoption of this technology to assist students with special needs were found to include the students, their parents, their teachers, school principals, school ICT specialist teachers, the school council, the Web, microcomputers (Windows and Macintosh), laptops, iPads, software, Education Department policies, learning technology policy, the school environment, classroom environments, learning approaches and paradigms, delivery methods of instruction, engagement methods, thinking processes, technology infrastructure-bandwidth, curriculum, Internet resources, digital libraries and other related mainstream, and special schools (Adam and Tatnall 2010).

The methods employed in this research come from those of case study. Yin (2014) regards a case study as the preferred method for examining questions that ask the how or why of contemporary events or when the relevant behaviors cannot be manipulated. He believes that case studies use many of the same techniques as a history, but add direct observation and systematic interviewing. Case study evidence can come from documents, archival records, interviews, direct observation, participant observation, or physical artifacts. In this research study, key (human) actors – teachers and parents – were identified and interviewed about the use of ICT in the school. Questions to the teachers were broad and asked whether, and if so how, the use of ICT in the school had made a difference to the students' learning outcomes. Parents were asked to identify any changes in their child's attitude to learning and ability to perform educationally. The computers and software (non-human actors) were "interviewed" by examining their operation, instruction manuals, and facilities.

Following the main data collection period, contact was kept with Concord School through ongoing conversations with the principal and attendance at a Concord Conference in 2008. After completion of the initial research project, although access to these special schools was no longer possible (under Education Department ethics rules), follow-up discussions were also held over several years with principals and teachers from nearby and feeder schools to see if anything had changed from their perspective. These discussions suggested that what was observed during the case studies was still continuing, and perhaps even accelerating, after this period.

Case Study: Sunbury and Macedon Ranges Specialist School

Sunbury and Macedon Ranges Specialist School is a purpose-built school for students with learning disabilities. It has around 180 students with 70 teaching and support staff and provides a range of educational programs for students who present with special learning needs including global development delay, autism spectrum disorder, and physical, social, and emotional disabilities and provides an extensive curriculum consisting of Arts, English, Technology, Health and Physical Education, Studies of Society and Environment, Science, and Maths. In addition to delivering the key learning areas as part of the curriculum, the school provides a broad range of programs that are designed to further enhance the independence of its students. The school motto of "Consistency, Credibility and Continuity" is reflected in the curriculum delivered and underpins all that the school's website claims the school represents (Sunbury and Macedon Ranges Specialist School 2016).

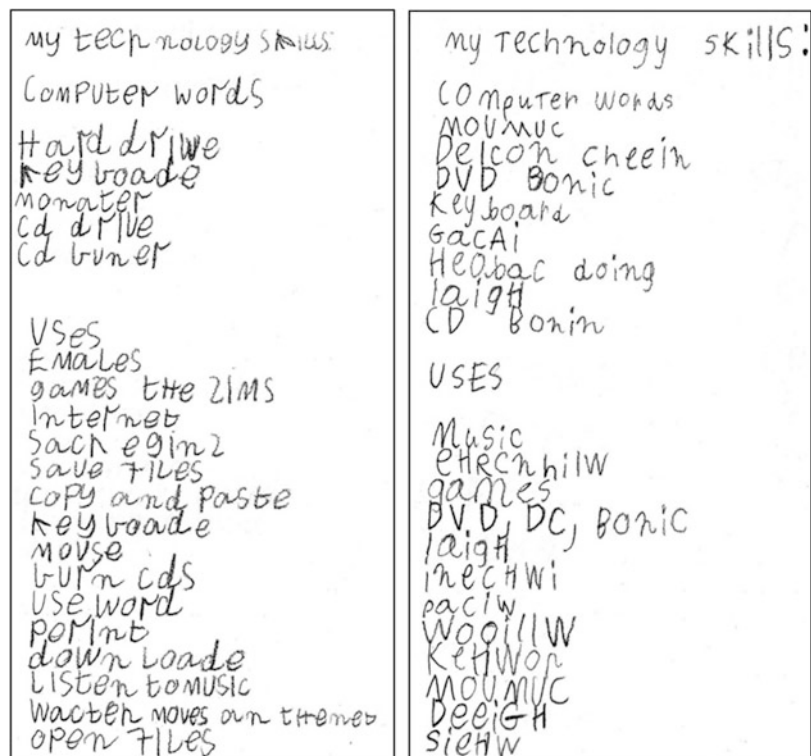
At Sunbury, ICT was used predominantly to reinforce language and numeracy skills. An examination of the school's technology policy and curriculum showed that the use of ICT was an integral part of classroom teaching and learning (Adam 2011) but that access was rather limited.

The reported research involved a small-scale project of observations and discussions with the principal and several teachers as well as a small group of students aged around 14. The students were of mixed cognitive and physical disabilities and in general were keen to use computer games (AbilityNet 2013) that reinforced certain skills like language or numeracy and literacy. The researcher chatted with a few students, Ben, Barry, and Teagan, and watched them play the Magic School Bus on Mars. This showed how puzzles were used in this setting to engage students and help them to improve their perception of space, time, age, and personal attributes (Adam 2011). The students investigated were heterogeneous in LD as there were both physical and cognitive disabilities present in the group. At the school there were certain students with severe physical disabilities. Several students needed help with the CTRL-ALT and DEL keys on the keyboard, and a few needed directions as to how to shut down the computer and the order that the various keys had to be used.

Overall though the students were familiar with their environment and were able to relate to and use technology in a comfortable manner. Parents were generally supportive for the initial ICT study and infrastructure. One technical task was setting up the infrastructure for links between different classes at the local level. In working between classes, the students showed a tremendous level of enthusiasm and immediate engagement when they began to communicate via web cams. The students were provided with an opportunity to respond to the researcher's open-ended questions relating to "My technology skills" and "Uses of technology." Figure 8 shows the list of skills and uses of technology from two of the students at the school.

Sunbury and Macedon Ranges provided a gateway into this research and facilitated an investigation of the infrastructure for school ICT. The results were very significant, enabling identification of the level of support both at the local school level and from the Education Department. The school was also instrumental in

Assisting Students with Learning Disabilities Through Technology,
Fig. 8 LD students' skills and uses of technology: early adopters



identifying Concord School, where a significant part of the study was conducted.

Case Study: Concord School

Concord School is a special school located in metropolitan Melbourne that caters for special needs students with mild to moderate intellectual disabilities from Primary (elementary) to Year 12 (senior secondary) levels. The students come from diverse socioeconomic backgrounds and are between 5 and 18 years of age. The vision of this school community encompasses a commitment to achieving excellence in education for students with additional learning needs through a curriculum which integrates learning technologies with best practice in teaching and learning. The values embraced by the school community are “Respect, Personal Best, Happiness, Cooperation, and Honesty.”

Concord has a teaching and educational support staff of 110 with an enrolment of about 400 students. The school’s website (Concord School 2016) proclaims that “Concord School is a government P-12 specialist school for students with additional learning needs. It provides a safe and supportive learning environment where students are challenged to achieve and reach their full potential.” It indicates that Individual Learning Plans are used to specifically tailor the educational pathway of each student to meet their targeted learning needs (Adam 2011). This is done through the use of good resourcing, class sizes of 8–12, and education support staff in each classroom. There is also specialized staff consisting of a school nurse, occupational therapists, speech pathologists, and student well-being coordinators. The school has an excellent IT Resource Centre housing the latest technological equipment for use by its staff and students. Classrooms are equipped with an electronic whiteboard, and each student has access to a notebook computer and iPad. The students at Concord School are encouraged with the school motto: “To be the best that they can be.”

For senior students in the school, the curriculum offers alternative studies such as the Victorian Certificate for Applied Learning (VCAL). ICT was clearly seen as a driving force for students

with special needs. Concord had a One-to-One (121) Information and Communications Technology initiative in its Transition Centre. In simple terms this required the school to invest in a computer (laptop or desktop) for each student, as well as other accompanying software and hardware (including a classroom interactive whiteboard) for VCAL students. The 121 ICT project offered opportunities for students to use technology that would improve their literacy output, access and exposure to technology, as well as increasing engagement (Adam et al. 2006) and provides evidence that scaffolding with a direct teaching approach enhances the learning outcomes of LD students.

In addition, the study further demonstrates that infrastructure is a significant factor in the successful adoption of ICT in these schools. A major part of the reported research was related to VCAL studies, where the students’ daily work was aimed at completing the set tasks. In addition this program provided access to work and further study with the assistance of local organizations and programs from tertiary institutions. In terms of learning outcomes, the students were involved in activities that allowed them to become familiar with current events, national issues, and disasters (Adam 2011). The ICT programs and environment were reflected in the attitude, motivation, and communication skills of the actors.

Overall, observations and discussions at the school found that a strong focus on the use of technology in teaching and the curriculum can lead to stronger engagement by students and teachers. Although in some cases students faced difficulties with motor skills including writing, drawing, spatial perception, and speech, it was observed over a significant time period that these handicaps were often overcome with the use of ICT. For example, folding a blank sheet of paper to make an envelope and then writing their address on the front of the envelope were very difficult for some of the students. However, almost every student was able to use a laptop and a Word Processing program to do this. It was also apparent that some of the students demonstrated ICT skills beyond what was

required in class, and because of this, they tended to show frustration with the teacher in class. The activities appeared to be commensurate with the standard of the students, and the main activities observed included personal development, office skills, and ICT studies (Adam 2011).

The school principal fully supported the research and felt that the school could only benefit from an independent examination of the way ICT was used and how it could be further used to support the 121 project. This was a key actor who displayed very strong leadership, and this was recognized and respected by the school staff, students, and other stakeholders. He was an early adopter of the technology and held the belief that students with LD could be assisted by the use of technology or ICT in the classroom. This actor saw the strength of the school in the strong bond that it had with its students. Everyone in this school community – teachers, parents, assistants, students, and ancillary staff – all had access to the principal who was active and involved in the affairs of the school and very supportive of ICT projects implemented. This was a very enthusiastic actor about innovation with technology and organized work on the infrastructure to get the classrooms ready. His interview comments included the following (Adam 2011):

- “I want to see the students to be active participants in their own learning that leads to specialization in technology.”
- “This empowers students (disabled or not) to control and self-manage their own learning at school and at home and hence become lifelong learners with access to technology and skills.”
- “Technology provides skills so that they can be seen as normal workers and have gained an understanding to take on the role beyond school.”
- “The focus is on collaborative learning with students becoming social and collaborative learners.”

A number of teachers were observed and interviewed on a regular basis, and all

demonstrated full support for the school leadership and vision in regard to ICT. They were all very strong users of ICT, having their own laptop, used email, and also accessing the school’s internal resources through a shared medium (SharePoint). They worked well with the students and implemented school policy, agreeing that ICT was an enabler for the students and that it would improve their learning outcomes, particularly since it was integrated into the curriculum. They showed adequate technical skills and willingness to adopt new technologies. The following comments displayed their belief in ICT:

- “This is an exciting step for students, teachers, and classrooms as it is social and collaborative technology – it is never boring.”
- “Yes and they are growing in an environment where the world is at their fingertips.”
- “It is a whole new classroom that is not contained to that physical building of the school.”
- “It’s not just about playing with a new toy – it’s exciting because it connects you with others.”

Parents of students from several classes were asked to respond to a questionnaire, and the response rate was very high and showed a positive attitude for the use of ICT in the classroom. Several parents indicated an awareness of the use of ICT in the curriculum by the school, and their responses showed that they felt there were still gaps in how technology could assist their child in both school and life. However, they indicated that they had identified a positive gain from ICT and acceptance of the school’s work and curriculum. Parent responses included (Adam 2011):

- “Provides confidence, very useful information, spelling, solving problems, skills for the job, and skills for the home.”
- “Ability to use laptops and programs not at home.”
- “Gain independence in writing and money skills.”
- “Have good understanding of various computer programs, source information, look up

bus tables, concert tickets, movies, starting times, etc. independently.”

- “My daughter’s limitations reduce the degree to which she can use ICT, great learning tools as she is a very visual child, and she likes to be alone often.”

Concord School, Transition Centre

The Transition Centre caters for approximately 60 to 70 students from Years 10, 11, and 12 with the aim of facilitating their transition from school to further education or to work, through learning programs that offered an applied learning curriculum. This could be followed up through courses at a local training organization. The practical and pragmatic approach adopted by Concord was that its Transition Students are provided with a curriculum with a strong focus on ICT. In Year 10, students complete the pre-transition learning program designed to prepare them for their post-compulsory schooling. In Years 11 and 12, students complete either their VCAL or a Special Needs Learning Framework program designed by the school. This ensures that learning continues during and after the transition process and is recognized for employment and educational purposes. It also provides a safety net for school leavers.

The practical and pragmatic approach adopted by Concord is that its Transition Students are provided with a curriculum with a strong focus on ICT. And this subsequently can be seen as a vehicle that allows the students to build lifelong skills. From the USA, the “Individuals with Disabilities Education Improvement Act” mandates equity, accountability, and excellence in education for children with disabilities and provides recommendations in regard to the assessment of standards of LD students in the preparation and continuity beyond college. Concord’s Transition Centre echoes these ideas. ICT is embedded in the curriculum and the beliefs of staff and school community at Concord. It is a strong vehicle and enabler for good pedagogy as it reinforced the communication skills and engagement and is a clear indicator and facilitator for school to work transition (Adam 2011).

This study provided strong evidence that ICT can equip LD students with adequate skills

which allow them to continue with further study through pathways to higher education at a local polytechnic or university. This subsequently can be seen as a vehicle that allows the students to build lifelong skills. The research also showed that LD students can increase their job opportunities as the ICT skills they learn can minimize the impact of their disability or learning difficulty and thus enable them to attain a normal work environment.

At an academic conference in 2007, the ICT coordinator described how Concord School had introduced and trialed the use of social software and networked learning activities and practices. He described the use of relevant software at the time such as Lumil, WordPress MU, ccHost, Urdit, Gregarius, Scuttle, and Firefox by the students at all levels in the school. Table 4 gives a summary of the activities undertaken and what they achieved. Understandably, these have been superseded by more recent programs and tools, but the presence of these strongly demonstrates the significance of this actor.

An Actor-Network Analysis of the Use of ICT for Students with LD in These Schools

Any analysis using ANT deals not so much with the actors themselves as with the interactions between actors and their networks, so ICT is only important here in its interactions with the LD students. Both schools only had significant ICT programs and provided good ICT facilities and student encouragement due to the interactions of their principals with teachers, parents, and the Education Department. The classroom computers are only able to interact with students due to their prior interactions with the school ICT coordinators to prepare workstations, software, and Internet connections. The most important interaction here though is between the students and ICT facilities. We will discuss the data, primarily from Concord School as this was most significant, in accordance with ANT innovation concepts, namely, problematization, interessement, enrolment, and mobilization of actors (Callon 1986) similar to Shaddock (2007).

The leadership of key actors, including the principal, ICT coordinator, and several leading

Assisting Students with Learning Disabilities Through Technology, Table 4 Trialed social media activities undertaken at each section of the school

	Junior	Middle	Secondary	Transition
Using photo-sharing social software to locate suitable photos for use in other work by searching with tags	X	X	X	X
Using photo-focused social software (tagging and comments) to share artwork created with GIMP			X	X
Using photo-focused social software to annotate photos to identify key information and demonstrate learning about horticulture				X
Using photo-focused social software to share sound notes recorded at when the photo was taken to demonstrate learning and understanding				X
Using photo-focused social software to create albums to identify and celebrate a range of learning activities and experiences		X	X	X
Using photo-focused social software to comment on successful learning				X
Using photo-focused social software to easily locate photos for student blogs (digital portfolios)			X	
Using blogs to celebrate and reflect on student learning			X	X
Using ccHost to share scratch sprites, backgrounds, and projects to encourage remixes and collaborative work				X
Importing scratch sprites and reusing and modifying the work of others	X			X
Using ccHost to share audio samples to encourage networked and collaborative learning				X
Using music-focused social software to develop social software skills and activities and create an online presence			X	
Searching music-focused social software using tags to find suitable music for use in other work		X	X	X
Using a web-based feed reader to read aggregated student blog content to facilitate interaction			X	X
Using social bookmarking software to share web resources and encourage networked learning			X	X
Using shared scripts to scaffold use of social software and other internet sites				X

team teachers who worked in the 121 ICT project, all problematized (Callon 1986) the vision of integrating ICT in the curriculum. The most important actors and their interactions were:

- Ten students of mixed cognitive and physical disabilities at Concord were observed working and interacting with teachers and assistants from the senior class in the 121 pilot project. Their main interactions were with their teacher and the school computers, and they were all keen to use computer games. These acted to reinforced skills like language, numeracy, and literacy. They were also able to exchange email with the principal.
- Parents as actors had their own voice and networks and problematized their own way via the school council and supported funding.
- The principal is very much a leadership actor, gatekeeper, strong voice, and power in the school council. He insisted protocols were followed and held a very strong view on the technology, users, and role of technology on learning.
- The ICT coordinator was another leading actor who was recognized for his skills and knowledge. He was assigned the task to enroll other actors and extend the 121 ICT pilot to the rest of the school. He was an innovator who introduced modern technologies and was

very highly regarded by other actors. He problematized ICT curriculum by applying his ICT skills. He also possessed previous experience from working with specific Education Department projects to train others.

- Leading teacher (1) was a key instigator for the 121 project in 2005 and a willing user of ICT in classrooms. This actor problematized the 121 ICT project and the necessary infrastructure for its delivery, possessed high communication skills, and was very capable in mobilizing other actors.
- Leading teacher (2) was highly trained in special needs work and an engaged ICT user. This actor problematized curriculum studies by integrating ICT in general VCAL studies.
- Computers and other technical objects (in ANT, known as immutable mobiles) and their interactions with students were highly significant. For instance, it was amazing to notice the students' reaction to the tablet PC when they saw it for the first time.

The interactions between the students and computers indicated their considerable interest in ICT and showed that their teachers were able to help them in catching up with schoolwork, looking up words in the dictionary, preparing oral presentations, working on the computer, working out things together, and similar activities. They were clear and accurate about who managed the school and the class they belonged to and clearly identified with their home group teacher. In some classes, they were given responsibility to check the attendance roll and organize orders for the store and lunches. They also collected and distributed laptops and trolleys between classrooms in an orderly manner and appeared happy to go from one class to the next and participate in the activities on hand.

The school learning model developed and changed in response to need and the availability and type of resources. It was proactive, and its focus was on addressing the current needs of students, parents, and teachers. For example, inclusion of social networking concepts like

blogs was introduced in 2007. This enhanced the way ICT was used in the classroom with students engaging and producing work of higher standard and displaying stronger skills. All this curriculum development was done within the frame of Education Department policy.

Conclusion

The research showed that use of ICT enhances LD students' independence and equips them with adequate skills which should allow them to continue with further study through various pathways and to move into a normal work environment. It also demonstrated the importance that key actors, such as the Concord school principal, have in facilitating the adoption and use of ICT with these students. It was observed that in certain activities that required physical or motor skills, some students were able to overcome these with the use of ICT.

Although Concord did use some performance indicators internally and externally through the number of students completing VCAL, in this entry, it has not been argued that test results and better educational outcomes in the commonly used sense of the term were necessarily improved. It has been argued, however, that ICT can be seen to be an enabler for good pedagogy with these students.

The research found that the most effective manner for teachers to implement programs using computer-based technology is to integrate the technology into the curriculum. In doing so, the special needs students gain lifelong skills and enhance their self-esteem and communication skills. ICT is shown to be an enabler for good pedagogy that can also set a pathway for the transition from school to work or further study for these LD students. It does not change the nature of a subject but has the capacity to integrate and consolidate several areas from the field of study or curriculum. This study found that ICT was applied to teach image refinements,

certificate designs, or artifacts in office skills at Concord.

The research data from the case studies demonstrate the power of both human and non-human aspects of the socio-technical network that staff and students construct around LD and the benefit of using ICT in their education. The study provides evidence that for LD students, a significant attainment in skills and academic knowledge is facilitated by the adoption of ICT. This data showed that a strong focus on the use of technology in teaching and the curriculum can lead to stronger engagement by students and teachers. The study strongly supports that ICT increases the motivation, independence, self-esteem, and communication skills of LD students and aids in facilitating transition to work. At least in this respect, producing a different result to that reported in the OECD study, made this research study very worthwhile. The results support the view that ICT has the power to interest, enthuse and inspire these students. This result is illustrated by the comment of one student who proudly said: "We were the first to use a laptop and a smart whiteboard in the school."

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Assistive and Instructional Technology

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Assistive Technology

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- ▶ [IT on Teaching and Learning Process of Visually Impaired Students](#)

Assistive Technology and Inclusion, Philosophical Foundation

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Introduction

Recently the World Bank reported that out of the 1 billion population (15% of world's population) experiencing some form of disability such as one-fifth of the estimated global total, or between 110 and 190 million people experience significant disability (WHO 2018). Technology plays a vital role for Inclusion as it increases the participation of individual and community at large in all walks of life. Various revolutionary

innovations such as artificial limbs, robotic assistance for feeding, Speech Generating Device (SGD), etc. enables individuals with disabilities more functional capacities.

In general, definition of assistive technology comes from the Assistive Technology Act of 1998, which was amended in 2004. The amendment defined assistive technology as “any item, a piece of equipment or product system whether acquired commercially off the shelf, modified, or customized that is used to increase, maintain or improve functional capabilities of individuals with disabilities” (Cook and Polgar 2014, p. 2). But there is also myth regarding thinking aspect of assistive technology, namely, “technology panacea myth,” that means a psychological state when individuals with disabilities and other related person think that technology itself enables an individual with disability function as without disability (Quist and Lloyd 1997). However, this may not be rightly defined and may actually be the outcome of lack of knowledge regarding the philosophical view of technology and fundamental design principle.

Therefore, this chapter mainly focuses on two different sections: *firstly*, the chapter discusses the philosophy of technology and shows how in the context of philosophical orientation, theoretical and conceptual frameworks of assistive technology are being developed. *Secondly*, it focuses on universal designing aspects of assistive technology. The chapter intends to redefine assistive technology based on these two aspects in the context of inclusion and tries to answer some questions related to mainstream technological design. In a major aspect, this chapter seeks to explore some of the basic questions related to technological design and its use in the context of assisting the people with disabilities in the context of inclusion such as – how an assistive can be defined in the context of inclusion? Besides, this chapter will also explore an overview of how the knowledge of philosophy for technological design is crucial to designing an assistive technology device for inclusion.

Philosophy of Technology for Inclusive Accessible Design of Augmentative and Alternative Communication (AAC)/ Assistive Technology (AT)

This is a relatively new concept in terms of Augmentative and Alternative Communication (AAC)/Assistive Technology (A.T). This section will reflect the philosophical overview of technology. This is important because technology itself is not a miracle which can bring change and enable people with disability function like without a disability. The success of any AT always is based on design and functions of the specific device with respect to the context be it environmental, cultural, psychological, etc. Therefore, in order to understand technology properly in the real sense, there is poignant need of understanding the underlying philosophy. Any designer, user, or family member of user and practitioner needs to know more about the nature of technology through the lenses of philosophical inquiry to understand the essential approaches needed to use AT in inclusive settings.

This section is organized through different domains of the philosophy of technology which is mutually interrelated in the context of AT design and inclusive accessible viewpoint. Next part provides an overview of the philosophy of technology as a contribution on a theoretical and conceptual basis of AT and at the end draws some conclusion from the point of view of design and application of AT.

Researchers are very much interested in the philosophy of science rather than the philosophy of technology. However, quite recently philosophy of technology is also getting an increasing amount of interest and attention among the researchers. The most comprehensive viewpoint of philosophy has been given by Carl Mitcham (1994) in his book “Thinking Through technology” where he conceptualizes it from three aspects/angles: “technology as artifact,” “technology as knowledge domain,” and “technology as social values” (Vries 2010b).

Technology as Artifacts

Mitcham believed that every technology is an outcome of “Artifact.” But generally, people are not aware of the artefact and think that everything can be technology. In any circumstance everywhere is an artifact, but people associate them with technology. In the field of technology for people with disability, in many ways people just assemble amount of artifact to diminish the specific obstacles for people with disability and called it as a technology. Therefore, artifact is one of the direct ways of connection with technology. Another way we can define “artifact” is as a functional nature of “natural object.” So here one needs to clarify the complimentary concept of “artifact” and also explain why artifact is different from “natural object.” According to Meijers (2000), artifacts incorporate two different natures with specific properties:

- (a) **Physical/structural properties:** Physical or structural properties of artifact refers to the element of an object. For example, think about ones’ smartphone, one can describe the phone based on its elements (such as plastic), size (5 in.), color (black), weight (5 gm.), shape (square), etc. But one who is not familiar with a phone or its function, may think it as an object for dressing hair or even digging soil.
- (b) **Functional properties:** Alternatively, “smartphone” can be described based on its functional aspect such as one can talk through it from a distance or the Internet can be surfed by it etc. Now, who is not familiar with this can imagine some of the basic images such as how the object looks like, or its shape, and so on and so forth.

Furthermore, these two descriptions of an artifact are incomplete without a combination of both. Such as only physical/structural properties cannot give the whole image of an object or vice versa. So now if one tries to know about “natural object,”

there is only physical/structural properties and no functional properties. It is the human who defines the functional properties of an object and makes it an artefact. This concept will be further analyzed by providing examples from the assistive technology point of view. For instance, suppose when one thinks about a “rubber” while someone uses it as a pencil grip for the student with Tourette syndrome (i.e., who has difficulty controlling motor pattern for writing). In that situation, “rubber” is a natural object and that is the human who ascribes “function” aspect to it (viz. use it as a gripper). In that way, natural object (here rubber) can have many “function” such as it can be used for hair binding or pencil gripper and many more ways. However, in that situation, natural objects will be treated as an artifact. Therefore, size, weight, or color doesn’t depend on the idea of rubber, rather “function” does (Vries 2010b).

Moreover, from the functional view of artifact, Hendrik van Riessen (1938) discussed about “aspects of reality.” “Aspects of reality” means functions of artifact from different aspect. He also elaborated that every artifact may have 15 aspects of reality. Some of them are as follows:

- **Spatial aspect of reality:** Every artifact occupies a certain amount of space. So, designer of any artifact must take this into account.
- **Economic aspect of reality:** Every artifact has its own value (from the economic aspect – the price tag). This value depends on what “function” someone ascribes for it.
- **Social, judicial, aesthetical, ethical, and belief aspect of reality:** This aspect means belief or distrust in any technology.

Another viewpoint that may be important to discuss here is that every artifact will have subjective as well as objective functions. Such as in the physical interaction point of view, pencil gripper, as an assistive artifact, can function as both subject and also object. Subjective in the sense, pencil gripper can itself diminish the

problem of writing for Tourette syndrome and objective in a view that human beings can change or modify pencil grip for his/her own convenience. Therefore, designer of any assistive technology or better to say who ascribes function to any artifact must reflect its various aspects such as passive, active, or both in order to function it as desired.

Now another important aspect necessary to explore here in order to get a sound view about designing any AT are the following:

- **Proper function:** Proper function refers to a specific function which designer (or any human) had in mind when he/she ascribed functions on it. Such as pencil gripper can be used in many ways but the designer who designed it, ascribed function of writing as a pencil.
- **Accidental Function:** But the element or physical property of pencil gripper can be used in several ways such as someone can use it to resist the pen falling down from the table. That is the accidental function of an artifact. It is very common that the accidental function may work properly because physical elements of specific artifact are fit to do that.
- **Improper function:** Suppose someone wants to use pencil gripper for breaking the glass but it doesn't work because physical properties don't allow doing this. Therefore, it may be considered as improper function.

From the functional aspect, Van Riessen also discussed two distinct functions of an artifact such as foundational function and qualifying function.

- **Foundational function:** The foundational function of any artifact refers to the origin of an object. Such as a stone was formed by many physical processes that is why one can say that a stone has its foundational function in the physical aspect (Vries 2010a).
- **Qualifying function:** Qualifying function refers to ultimate contribution of any object to the meaning of reality. For instance, for a

pacemaker the qualifying function of reality is that to produce the correct electric pulse. This can be characterized as technical function. Varies (2010b) described that the qualifying function of a train is in the social aspect such as carrying people together. But this "social aspect" can only take place when train fulfills the technical function that is the "spatial aspect," i.e., going from Place A to B.

In the view of the previous example of pencil gripper as an assistive technology, the element of rubber gripper or wood for pencil has had its own foundational function separately.

Apart from all foundational or operational functions, there is another crucial aspect of an artefact which corresponds to "operation" or "functioning in a specific action." It means that application of multidisciplinary way to derive knowledge about physical and functional properties to predict how a specific artifact behaves in a certain action. In that situation, effective design of an artifact should reflect the desired function. Additionally, an artifact can be consisted of many parts; in that case, artifact denotes a "system." A system is a combination of many parts of an artifact working together.

Here an overall discussion about the philosophy of technology as artifact provides background knowledge about how philosophical reflection of technology can influence the design of any assistive technology. This knowledge is pertinent to design an assistive technology for an inclusive setup. Many times it has been observed that poorly designed assistive technology stigmatize student with peers without disability (Hayhoe 2014). Only awareness or academic setting through assistive technology doesn't contribute to the process of inclusion of people with disability (Krüger and Berberian 2014), there is necessity of ascribing function to it. Many assistive technologies mainly focuses on hardware or software function rather aesthetic aspect of reality, the cultural aspect of reality, and social aspect of reality (as discussed in the previous section) in context of mainstream settings. The subsequent section

of the chapter is going to discuss another important aspect, namely, design principle of AT for inclusion.

Design Principle of AT for Inclusion

The concept of “inclusiveness” refers to equitable or equal opportunity or participation of the “people with disability” by providing them a platform where they can exhibit their different abilities with their neuro-typical peer (Ahmad 2015). Though various AT has been developed to assist the “differently abled” community, there are always emerging needs and challenges to tailor-made or personalize the design of AT device to increase more participation in an inclusive setup (Carmien 2016).

This section focuses on the designing principle provided by Quist and Lloyd (1997). Quist and Lloyd (1997) portrayed six standards of AT which are needed to be taken into consideration when designing any assistive devices. The six standards are as follows: (a) Principle of parsimony (b) Principle of minimal effort (c) Principle of minimal energy (d) Principle of minimal interference (e) Principle of best fit (f) Principle of practicality and use, and (g) Principle of evidence-based practice.

Principle of Parsimony

Everything should be made as simple as possible, but not simpler – Albert Einstein (Reader’s Digest in July 1977)

“Principle of Parsimony” refers to that a design of AT should be simplest to increase effectiveness and efficiency (Quist and Lloyd 1997). Complex design can be a very effective solution but that can also create barriers for users, especially those who have struggled with various physical and mental challenges. Therefore, when designing or selecting any technological devices, the designer and end-user should be concerned about unnecessary complexity and implement easy to understand approaches (Jones 2002). Generally, in daily life activities, people are intended to use various complex

solutions which can easily be substituted with the simplest solution (viz. inexpensive, reliable, and easy to transport) (Lee and Johnson 2017). For example, those who have “Tourette syndrome” or difficulty in a motor pattern for learning, one of the major struggles is “writing.” Therefore, he or she can easily buy “voice recognition software” for writing or can use low technology such as “pencil grips.” But if both this technology helps in writing then choosing simple one is the less expensive, easy to transport, and less time consuming (Quist and Lloyd 1997). By diminishing complexities, active participation may be enhanced and hence inclusion can be improved.

Principle of Minimal Learning

Don’t Make Me Think – Steve Krug (2006)

Another hindrance for active participation or inclusion of people with disability is the use of poor design while developing AT devices that require additional thinking or mental effort to use or understand the function (Malcolm and Roll 2016). The principle of minimal learning refers to less cognitive load aspects when using devices. For example, in 9th grade, the teacher gifted a new design pen to all the students in the class. There were various instructions given by the pen company regarding how to open the pen and write. However, after sometime classroom was getting too much noisy and lots of queries were poured in to the teacher, lots of broken pen in hand for the inappropriate opening and lots of frustrated faces. So, why this situation happened? The answer is as the designer of the pen company did not maintain the principle of minimal learning. Therefore, to use or understand the function of pen, the users required more mental effort which increased the cognitive load and decreased the motivation to use it (Malcolm and Roll 2017).

Therefore, in the context of designing AT devices, designer should be concerned about less instruction on how to use it. King (1999) pointed out it as “operational knowledge,” knowledge regarding “how to use” or “operate” any devices. Quist and Lloyd (1997) noted that if any device

required more “operational knowledge,” it likely reduces the use of the device over and over time by the user.

Principle of Minimal Energy

Minimum effort means maximum comfort – Cited by Aarts (2006)

Minimal energy refers to the least necessary mental and physical effort for any task performance. Research has shown that task which required huge energy for task performance, there will be less motivation about specific task completion (McDonnell et al. 2003). This can be worst in context of people with disability. Quist and Lloyd (1997) found that AT user most likely to avoid any task performance if there is need of too much energy. Therefore, designer of AT must take into consideration this principle to increase performance for long period of time. From the designing perspective, the Center for Universal Design at North Carolina State University (1997) provides some guidelines to minimize effort in task performance. Some of those are natural body position of user which should be maintained in any design. Those are the following:

- Reasonable operating forces should be executed.
- Repetitive action should be minimized.
- Sustained physical effort should be minimized.

In the context of AT device, this principle can be utilized for motivation or to execute a behavior. Any user can be withdrawn from any task related cognitive load or mental effort and physical effort that is more than the motivation of user.

Principle of Minimal Interference

Stop brothing me! – Cited by Quist and Lloyd (1997)

This principle emphasizes that any design of AT should create a distraction-free environment. This principle is important to take into consideration as if any AT design has more complex or multiple features then attention of any user will be engaged in operating the device rather the task performance (Shaffer 2017). In such situation extrinsic cognitive load will be increased; therefore, the user may

experience low motivation from the required task such as learning activities or communication.

Principle of Best Fit

Is it me? – Cited by Quist and Lloyd (1997)

This principle emphasizes on individualized design of any AT. A designer should be aware of the target group or individual to design a “best fit” device based on personality or need of individual or community to the maximum extent possible. Quist and Lloyd (1997) stated that design which is compatible with user need and the personality of a user AT becomes more effective for people with disabilities. Ergonomic or understanding the human factor is major study area in the field of any technological design. King (1999) claimed that 75% success of any AT device is related to the human factor.

Principle of Practicality and Use

Never forget why you started – Cited by Quist and Lloyd (1997)

This principle supports feasibility and practicality of any AT device. Design of any device needs to be consistent with the availability of resources. Therefore, this principle emphasizes to apply previously mentioned all the principle from the practical ground. For instance, mental effort, cognitive aspect, physical or environmental aspect need to be taken into consideration based on the availability of resources. In a simple way, this principle encourages to develop a solution which can actually use in real-world context. Therefore, designer should keep in mind economic, social, mobility, psychological aspect, etc., while designing devices (Hayhoe and Simon 2014; Yu and Liang 2013).

Principle of Evidence-Based Practice

Stand on the shoulders of giants – Isaac Newton on Letter to Robert Hooke in the year of 1676

Another important principle for designing an AT device is Evidence-based practice (EBP) (Thistle and Wilkinson 2015). Schlosser (2003) stated three aspects for EBP such as (a) use of best and most current research as a reference for design (b) focus multidisciplinary team or expert approach (c) need to take all the stakeholder perspectives in

consideration for best services. EBP is the most critical aspect of AT development for any technological design for the following ground:

- Research-based pieces of evidence can help educator or designer towards effective implementation of AT for assessment and intervention (Schlosser and Raghavendra 2004).
- EBP increase accountability through a literature survey and help to find out effective strategies and interventions for present and future design of AT (Logemann 2000).
- EBP helps to provide insight regarding equal weight to unique client (Schlosser and Sigafoos 2009).

In this particular discussion, it has been observed that for designing effective AT devices the designer should know the fundamental aspect of technology from the philosophical viewpoint. Besides, a designer needs to know design principles to develop new forms of mainstream technology through innovation. In fact, we are living in an innovation era, where every nanosecond we are witnessing innovating some or the other new technologies. This is also true in the field of AT devices. This is privilege for us, however may not be every time. Because this may create a problematic situation in the context of inclusion, therefore, we need a serious (Re) philosophical evaluation of any AT so that it can contribute most effectively and purposefully to the mainstream technology or inclusion. Based on the reflection above, the next section is going to conclude assistive technology in the context of inclusion and intends to answer some relevant philosophical question in the context of design and functions of assistive technology.

Conclusion

Now coming to the end of the whole discussion, after providing general knowledge about the philosophy of technology in the context of AT including knowledge about design principle for designing effective AT device, the final section intends to link together and try to redefine technology as an assistive approach in the context of education. Here one tries to answer two specific

mutually exclusive questions; (a) What is meant by assistive technology in the context of inclusion? (b) How designers can use the knowledge of philosophical aspect for designing such inclusive technologies?

A straightforward approach to answering the first question is no people with disability should separate from his or her nondisabled peers by using any AT device. As discussed earlier that poorly designed assistive technology stigmatize student with nondisabled peers (Hayhoe 2014). Therefore, technology needs to be inclusive. Hayhoe (2014) also discussed inclusive technology is such technology that encourages social inclusion in the context of communication and interaction for the people with disability. The philosophy behind the inclusive approaches in AT technology and design is that it is our fundamental right that everyone should have social and cultural equality in the context of education and communication.

Consequently, the second question can be answered from several points of view. One of major important aspect needed to be taken in to consideration is (re)shape and (re)define the terminology “assistive technology” (Hayhoe 2014). This can only be done when designers of assistive technology shift their focus from the design of AT for people with disability to inclusive designs by addressing the social and cultural inclusion issues in their design. Additionally, need to design any device, not customer-led rather the intention to assist for whom the technology is created. To make a drastic shift in the context of assistive technology for inclusion, there is poignant need to provide encouragement and training to people with disability so that they are skilled to make their own devices (Simon 2014). Furthermore, it needs to be emphasized that people with the disability still have human capital that is valuable to their society.

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Assistive Technology and the Gifted Learner

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Synonyms

Acceleration; Distance learning; Gifted; Online learning; Web-based learning

Assistive technology is generally defined as piece of hardware, software, or other product that is used to help individuals perform tasks that might otherwise not be possible – especially those with cognitive and physical impairments (ATiA 2018). In the USA, a federal definition for assistive technology exists and policies and regulations provide protections and exclusive rights for those with disabilities needing certain technologies. Though not legally binding, some individuals have broadened the definition to include anyone who needs special accommodations in order to access appropriate learning, including gifted learners (Ellsworth 2018). Some states and higher education institutions in the USA consider gifted students within the special education umbrella and require that districts write Individualized Educational Plans for them. While the same federal legal rights do not apply, the individualized plan within a state allows gifted students to access learning tailored to their needs. Still, it may seem counterintuitive to consider gifted learners as a population that requires or benefits from assistive technologies. When one does think of assistive technology and gifted together, generally it is because a student is twice exceptional, meaning they are identified as gifted and also have a cognitive or physical impairment.

It may be argued, however, that gifted children differ from the general population in ways that require special accommodations and services not typically provided in the general classroom in order to continue learning at an expected pace and as to not impede their rate of learning. Gifted learners differ from their same-aged peers in a variety of ways. They are more likely to make complex connections within and across disciplines, learn (and retain) information more quickly, and understand abstract and theoretical ideas at deeper levels. They require accelerated instruction with appropriate levels of challenge and pacing in order to excel (Thomson 2010). Without the necessary accommodations, gifted students are less likely to show learning gains that are commensurate with their abilities and to achieve at expected levels (NAGC 2010). Consider, for example, a 6-year-old gifted student who already understands plot development, characterization, and how

language impacts a story but has not yet developed fine motor skills to write down all of her ideas because her physical development is not synchronized with her cognitive development. She may benefit from assistive technology to help her convey her ideas and continue learning and practice new concepts at a pace necessary for her until her fine motor skills develop enough to write the stories independently. As such, the use of assistive technology supports her cognitive development and eliminates the fine motor development concern that could have impeded her learning.

Evidence suggests that the use of technology in gifted classrooms offers benefits to both students and teachers (Housand and Housand 2012) although there are limited empirical studies on the topic. Strategies such as acceleration, interaction with like-ability peers, in-depth study with authentic learning experiences, and access to opportunities, mentors, or more knowledgeable others are effective ways to increase academic achievement and develop expertise (Rogers 2007; Subotnik et al. 2011). Technology may be used as a tool to implement such strategies to help gifted students perform tasks that might not otherwise be possible making it, in the broadest definition, assistive. In particular, the use of hardware, web-based approaches, software, online collaboration and discussion forums, and online coursework are the most studied interventions that have positive results for accommodating gifted student learning needs.

Hardware

The use of technology to develop content expertise, coupled with becoming more proficient in a variety of technology platforms, programs, and hardware can enhance gifted student learning and critical thinking. The use of graphing calculators, simulation tools, and digital drawing tools at earlier ages serves as a way to accelerate learning, allowing gifted students to become proficient in using advanced tools in a discipline at earlier ages consequently increasing conceptual understanding and spatial skills (Duda et al. 2010; Gadanidis et al. 2011).

Web-Based Approaches

Liu (2004) found that using specific hyperlinks (i.e., links to videos and online lectures and other advanced resources) increased gifted students' higher-level thinking skills and attitudes toward learning. The use of specific hyperlinks for independent learning also allows gifted students to adjust the pacing of their own learning and learn at a pace and depth more commensurate with their abilities, showing higher self-regulation skills (Greene et al. 2008).

Software

Software programs support individualized learning and advanced pacing so that gifted students can pursue areas of interest in depth (Sanderson and Greenberger 2011). In one study, e-publishing software allowed gifted students the opportunity to develop and showcase their talents at a pace appropriate for them and consequently they showed greater gains than those not identified as gifted (Gentry 2008). In another study, the deliberate use of game-based software allowed students to increase their problem-solving approaches and strategy development (Steiner 2006).

Discussion-Based Forums

Online platforms and discussion boards as well as collaborative games and software programs allow gifted students opportunities to develop social connections and interact with other like-ability peers. Students can engage with other like-ability peers to promote social-emotional health, share unique perspectives, and connect with others who have similar interests, regardless of age. Shin et al. (2013) found that the use of a software program that incorporated collaboration through sharing ideas about content and story designs increased the reported levels of friendships in

gifted students. Students participating in online or virtual forums may also find a sense of belonging not otherwise enjoyed or accessed in their schools (Cross 2004). Similarly, when educators used online discussion boards, students were more likely to collaborate and communicate with each other, thus developing more advanced thinking skills (Gadanidis et al. 2011). In another study, students who participated in online learning courses reported that one of the positive aspects was the socialization. Further, gifted students reported being more open-minded to different perspectives (Blair 2010) although students still wanted face-to-face or voice interaction with instructors (Olszewski-Kubilius and Lee 2004; Gadanidis et al. 2011); they also preferred online resources with hard copy textbooks as opposed to strictly online work (Gentry et al. 2007).

Online Coursework

The use of online coursework allows educators to individualize and tailor learning to each learner's unique strengths and needs in ways that are not typically provided in the general classroom. Teachers of gifted students might lack the qualifications to teach courses in the subjects their gifted students are interested and proficient in. Moreover, schools may not offer the number or types of advanced courses necessary to support the unique needs of gifted students at a pace or depth necessary for them to continue learning. With the help of computer-aided instruction and online courses, teachers can provide students with the resources needed to continue to learn and develop expertise. Specially designed online courses for gifted students led by content experts as well as adaptive software programs that progressively increase in difficulty provide accelerated opportunities that may not otherwise be afforded. Access to websites such as museums, ask-an-expert forums, and virtual tours of historical places and related websites can be a powerful tool for finding answers to many student

questions. Free courses and lectures such as MOOCs, Ted ED, or Khan Academy allow access to accelerated content calibrated at a level commensurate with gifted students' unique abilities. However, teachers must be careful when selecting online forums for gifted students and ensure that the courses are tailored for gifted learners and appropriate for student use. When online courses are designed specifically for gifted students, they report greater interest in a learning (Wallace 2009), show advanced problem-solving skills, acquire more in-depth content, and score higher on Advanced Placement exams (Olszewski-Kubilius and Lee 2004). Gifted students also reported that the online courses served as a positive way to actively pursue areas of interest in deeper ways, participate in courses not typically offered at their school, to learn at a pace commensurate with their abilities (Olszewski-Kubilius and Lee 2004), and to enjoy more personalized instruction not typically found in face-to-face settings (Thomson 2010; Wallace 2009).

A few cautions must be noted when examining technology and gifted students – especially assistive technology. First, the literature on this topic is extremely limited. In a review of the literature, Periathiruvadi and Rinn (2012) found 24 empirical studies focused on technology and giftedness although 157 descriptive or conceptual articles were found. Many believe that technology can be used to help gifted students access and perform tasks not otherwise available, but there are a few clear empirical studies on the effects. Information on assistive technologies for gifted students who are twice exceptional (i.e., have cognitive or physical disabilities and are labeled as gifted) is almost nonexistent of the few that were available. One article makes recommendations for particular apps that build upon twice-exceptional students' strengths (Stewart 2009) while another highlight ways to use translation devices for gifted students, particularly those who are deaf or blind and from rural areas (Belcastro 2004) arguing that geographic limitations complicate access and technology can assist in equalizing this access for

those in remote populations who are also in need of assistive services due to a physical impairment.

Second, teachers may have an inaccurate understanding of differentiated instruction. It is not enough to apply technology with gifted students as a general instructional strategy. The use of technology alone does not make instruction differentiated. Technology, when used as a differentiation tool, is carefully selected and deliberately applied to help students accomplish or access opportunities not otherwise available. Merely giving gifted students access to technology is not adequate. Differentiation with technology for gifted learners is individualized and targeted to their unique learning needs and strengths.

Finally, professional development and training for teachers and students is required. Students need to know how to effectively and safely use and participate in technology (Siegle 2003; Siegle 2007) and carefully select appropriate sources (Housand and Housand 2012). Not only is it important for students to know how to navigate the world that technology opens for them but teachers also need to be trained to use technology in their classrooms; technology cannot be used effectively if teachers do not know how operate or integrate it into classrooms and lesson plans (Periathiruvadi and Rinn 2012). Students need to be trained to effectively conduct online research and use the tools at their disposal while teachers need to be trained so that technology can be seamlessly integrated into classroom settings. Competing priorities, high stakes testing, little to no planning time, wide ranges of abilities in one classroom, lack of access to appropriate resources, and lack of pedagogical and content expertise can inhibit a teacher's ability to differentiate instruction for gifted learners in the general classroom (VanTassel-Baska and Stambaugh 2006). Technology's benefit cannot be realized if students and teachers are unable to use it properly or current systems and policies are not in place to necessitate use. Moreover, not only do teachers need to realize how to use technology and keep up with the

fast-paced and ever-changing developments in technology but they also need to know how to apply it effectively as a differentiation tool (Shaunessy 2007; Zimlich 2015). Teacher attitudes, access to appropriate technology, student responses to new approaches, and funding approaches all impact the effective use of technology in the classroom for gifted learners.

In summary, the research on assistive technology and the gifted learner is nonexistent. Accepted definitions of assistive technology are narrowly defined and do not include gifted learners as a special population that requires assistive technology. This may be due in part to federal guidelines for funding as well as philosophical beliefs. Regardless of the definitions, it is well documented that gifted students have learning needs that necessitate attention and accommodation (NAGC 2010) in order to develop at a pace commensurate with their abilities. Moreover, gifted students can benefit from the use of technology in ways that allow access to accelerated learning, like-ability peers, and other opportunities not otherwise provided in their school to support their pace and depth of learning. Access to appropriate supportive software and hardware, discussion forums, and online courses improves gifted students' reported interest, critical thinking skills, test scores, self-regulation strategies, and social interactions. In this way, technology does assist students in performing tasks based on their ability in ways that may not otherwise be available, especially if they are from geographically remote or under-resourced areas or homes where access to advanced opportunities are not available. As future research emerges in this area, perhaps definitions can continue to be expanded to look at students on both ends of the learning continuum. One cannot forget to include gifted learners, including those who are twice exceptional, as another population whose learning needs require assistance in order to fully invest in human capital and harness ways in which technology assists in performing tasks for which one is fully capable if provided the appropriate resources.

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- Distance Learning
- Learning Strategies and Achievement of IT Students in Higher Education
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Attendance Marks

► Attendance Records, Educational Management

Attendance Records, Educational Management

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Synonyms

Attendance marks; eAttendance; Register; Roll book

Definition

Attendance can be defined as the physical or virtual presence at a learning environment either real or online. It can be measured as daily, morning/afternoon, or lesson based and has a variety of subclassifications as discussed in this entry.

Attendance is a key component of the educational management process as clearly learning can only occur when the learner is present in the learning environment and this normally requires attendance at a specific location. It may be mandatory through a legal framework or merely a requirement for the successful outcome of a course or exam.

Attendance records are a key part of all phases of the educational process from early years, primary, secondary, further, and higher education. They can take the form of handwritten documents, machine-readable records, biometrics, or automated through near field or similar technology.

Attendance can be recorded online, in person or by any other mode that indicates that the learner has been present in the learning environment.

However, it should be noted that although attendance may be linked to educational

advancement and learning in its most simplistic form, it has no necessary relation to this. While a student may attend 100%, they may not learn anything, while one who attends 0% may still pass a final exam. This, however, would not be true for some courses that require a minimum attendance to pass something which has an increasing popularity for educational institutions.

Recording Attendance

Historically attendance has been recorded by hand in a register or ledger. It is normally a legal requirement for statutory education although is likely to still be an institutional requirement where this is not the case.

In its most basic form, it is recorded as a binary mark either attended or not attended. However, a large number of additional statuses have evolved as reporting has become more prevalent.

For example, in England (DfE 2016), the USA (Marblehead Public Schools 2017), and New Zealand (Ministry of Education New Zealand 2015, attendance Code List 2015), the following are all used for various attendance types. These are shown in Table 1.

One of the obvious trends here is the number of different codes and absence marks that are available. This is often as a direct result of government reporting requirements as well as the desire for more management information made more accessible through the electronic collection and storage of attendance. In addition the distinction between authorized and unauthorized absence has also become prevalent as the reporting of truancy rates (unauthorized absences) has become more of an educational issue.

Since the year 2000 has started to be recorded electronically, this started with the use of Optical Mark Readers (OMR) in which preprinted register sheets are marked manually by the teacher and then fed into an OMR reader and the marks transferred electronically to a computer as shown in Fig. 1 (SIMS 2017).

However, as Strickley (2007) observes that although these forms were always filled in at the appropriate times, often they were not read into

the management information system (MIS) until the end of the day and at worst the end of the week. This meant the attendance records could not be used for truancy detection and prevention but merely as statistical records. This was, to some extent, due to the issues around the process of importing the sheets which could be quite time consuming.

The advent of whole school computer networks, Wi-Fi, swipe cards, and handheld appliances has meant that attendance can be recorded in real time at the point of entry into the learning environment enabling real-time recording, reporting, and remedy.

Finger prints and even retina scans have also been used for the purposes of recording attendance although there have been some legal and privacy issues here that make this method less attractive.

Key to any method is the requirement to cut down on administration in recording and the ability to monitor in real time.

To a greater extent, the advance of electronic attendance recording led to a more report-led model which in its own way created these complex attendance code systems as illustrated in Table 2 (Ministry of Education New Zealand 2015).

Legal Issues

In many countries attendance at schools is compulsory, enforced by law. As such the recording of attendance is a legal requirement, and the registers themselves are legal documents and therefore need to be accurate, secure, and held for a period of time. This requirement originally applied to manual records but now is applicable for electronic records as well.

In addition there are a number of statutory statistical and public reports that involve the use of these records and consequently their accuracy is paramount.

A result of the public publication of attendance records has, to some extent, resulted in the increase in the definition of absence above and beyond its original concept as illustrated in Tables 1 and 2.

Attendance Records, Educational Management, Table 1 Example attendance codes and meanings

Code (England)	Description	Meaning	Code (USA)	Description	Code (New Zealand)		
/	Present (AM)	Present	ABS	Absent excused	?	Not in class	Unknown reason
\	Present (PM)	Present	ABU	ABSENT- UNEXCUSED	P	In class	Present
B	Educated off-site (NOT dual registration)	Approved educational activity	ACI	ABSENT- CALLED IN	L	In class	Student is late to class
C	Other authorized circumstances (not covered by another appropriate code/description)	Authorized absence	COL	ABSENT- COLLEGE	S	Not in class	Sickbay
D	Dual registration (i.e., pupil attending other establishment)	Approved educational activity	DA	DISMISSED-ABSENT A.M.	D	Not in class	Medical appointment – doctor or dentist
E	Excluded (no alternative provision made)	Authorized absence	DM	DISMISSED- MEDICAL	I	Not in class	Internal school appointment
F	Extended family holiday (agreed)	Authorized absence	DP	DISMISSED-ABSENT P. M.	E	Not in class	or activity – dean, DP, sports administrator, coach, attendance officer, etc.
G	Family holiday (NOT agreed <i>or</i> days in excess of agreement)	Unauthorized absence	FT	FIELD TRIP	M	Not in class	Student absent due to short-term illness/medical reasons
H	Family holiday (agreed)	Authorized absence	GYM	OPEN GYM	J	Not in class	Justified absence – the reason is within the school policy
I	Illness (NOT medical or dental etc. appointments)	Authorized absence	HM	HOME and HOSPITAL	T	Not in class	No information provided – truant (or throw-away explanation)
J	Interview	Approved educational activity	LIB	LIBRARY	V	In class	Examination or unsupervised study – student is on the school site
L	Late (before registers closed)	Present	SIS	SUSPENDED- IN- SCHOOL	X	Not in class	Exam leave unsupervised study – student is off-site
M	Medical/dental appointments	Authorized absence	SOS	SUSPENDED- OUT-OF- SCHOOL	G	Not in class	Holiday during term time
N	No reason yet provided for absence	Unauthorized absence	SPD	SPORTS DISMISSAL	N	Not in class	On a school-based activity
O	Unauthorized absence (not covered by any other code/description)	Unauthorized absence	SRP	SENIOR PROJECT	Q	Not in class	Attending an off-site school – organized activity such as trip/camp

(continued)

Attendance Records, Educational Management, Table 1 (continued)

Code (England)	Description	Meaning	Code (USA)	Description	Code (New Zealand)		
P	Approved sporting activity	Approved educational activity	TA	TARDY-ABSENT- P.M.	W	Not in class	Work experience
R	Religious observance	Authorized absence	TD	Tardy dismissed	R	Not in class	Removed (temporarily) from regular class (internal school student isolation)
S	Study leave	Authorized absence	TDA	TARDY-DISMISS-ED- ABSENT	Z	Not in class	Secondary and tertiary program (including trade academies)
T	Traveler absence	Authorized absence	TEX	TARDY-EXCUSED- A. M.	O	Not in class	Justified overseas
U	Late (after registers closed)	Unauthorized absence	UTD	TARDY-UNEXCUSED	K	Not in class	Attending a teen parent unit
V	Educational visit or trip	Approved educational activity	UTR	TRUANT-UNEXCUSED	A	Not in class	Attending alternative education
W	Work experience	Approved educational activity	V	FAMILY ABSENCE	Y	Not in class	Attending an activity center
X	Non-compulsory school age absence	Not counted in possible attendances			F	Not in class	Attending an off-site course/ class
Y	Enforced closure	Not counted in possible attendances			H	Not in class	Attending a health camp/ regional health school/ residential school
Z	Pupil not yet on roll	Not counted in possible attendances			C	Not in class	Involved in justice court proceedings
#	School closed to pupils	Not counted in possible attendances			U	Not in class	Student is stood down or suspended

SIMS **PUPIL REGISTRATION FORM 1** **SHEET NUMBER**

INSTRUCTIONS Use only HB pencil when completing this form.
Mark like this 

Example:
Student Present  Student Absent  Student Late 

No.	Student Name	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY	
		am	pm	am	pm	am	pm	am	pm	am	pm
01		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
02		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
03		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
04		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
05		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
06		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
07		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
08		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
09		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
10		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
11		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
12		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
13		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
14		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
15		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
16		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
17		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
18		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
19		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
20		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
21		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
22		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
23		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
24		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
25		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
26		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
27		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
28		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
29		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
30		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
31		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
32		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
33		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
34		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
35		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
36		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
37		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
38		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
39		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca
40		Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca	Pi	Ca

Number Present 

FOR OFFICE USE ONLY Weekly Total Weekly %

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Attendance Records, Educational Management, Fig. 1 OMR sheet for SIMS attendance

Attendance Records, Educational Management, Table 2 Attendance codes and meanings New Zealand

Attendance Code List 2015

Key	
Green	Present for half day calculations
Red	Unjustified absence
Blue	Justified absence



School Code	Classroom	Reason (Business Rule)	Explanations – The following explanations are provided as common reasons why a student may be absent from school. The Truancy Code column indicates if the absence is Justified or Unjustified. This does not preclude the Principal from using discretion over any specific student absence	Truancy Code	½ day calc
?	Not in class	Unknown reason (A temporary code)	This is the initial entry for a student not in class and the reason is unknown. It will be edited as relevant information becomes available about the reason for the non attendance. If required, the SMS can be set by the school to automatically change the "?" code to a T after a configurable number of school days (eg 7)	U	A
P	In class	Present	Student is in his/her regular class (This includes supervised study)	P	P
L	In class	Student is late to class	School policy will determine when this code is used. Eg. School policy may recommend that a student more than 10 minutes late is coded "L". Note this code does not contribute to the student's or school's absence or truancy rate	P	P
S	Not in class	Sickday	Student is known to be in the school's sickbay	P	P
D	Not in class	Medical Appointment – doctor or dentist	Current legislation means this type of absence is counted as present for ½ day summaries. There must be documentation verifying the appointment. This code is not to be used for a stay in hospital. Use code "M"	J	P
I	Not in class	Internal school appointment or activity – Dean, DP, sports administrator, coach, attendance officer etc	This can include students who are out of class for various school appointments including: form teacher, dean, senior management, counsellor, sports administrator, coach, nurse, carers, as well as students on an administration activity such as messenger, collecting attendance etc. It does not include a student who has been removed from his/her regular class and sent to the administration area for disciplinary reasons. This student would be coded P in the class and the code would probably be changed to R by the senior staff member dealing with the student	P	P
E	Not in class	Student is absent with an Explained, but Unjustified reason	The explanation for the absence is accepted by the school as the reason for the absence. But the reason does not fit within the school's policy as a justifiable reason to take the student off school. (Even though the parents may consider the absence was justified and may have provided a written explanation). E.g. "Molly had to stay home to look after her younger brother". For New Zealand and overseas holidays use code "O" – see below.	U	A
M	Not in class	Student absent due to short-term illness/medical reasons	Student is at home, or in hospital, because of illness or other medical reason. Depending on school policy a medical certificate may be requested for prolonged illness. eg three days, or as policy requires	J	A
J	Not in class	Justified absence – reason for absence within the school policy	Unplanned absences such as a bus breakdown, accident, road closure, extreme weather conditions etc Planned non attendance such as national/local representation in a sporting or cultural event in New Zealand or overseas Approved absence (including overseas) can also include bereavement, visiting an ill relative, exceptional family circumstances or a Section 27	J	A
T	Not in class	No information provided – Injured (or throw-away explanation)	An absence where either no information is provided, or the explanation is trivial (throw-away). I didn't feel like Maths so I took the period off - I had to finish an important assignment I went down to the river - I went to the shops - we had a test and I wasn't ready for it	U	A
V	In class	Examination or Unsupervised Study – student is on the school site	Students sitting examinations at school (if the SMS can provide attendance marking during exams) Unsupervised study – school process verifies student is on the school site. Note that supervised study is recorded as a regular timetabled class	P	P
X	Not in class	Exam leave Unsupervised study – student is off-site	Code X will count as a justified absence and contributes to ½ day absence summaries. Note that supervised study is recorded as a regular timetabled class	J	A
G	Not in class	Holiday during term time	When a student is on a New Zealand, or Overseas holiday during the school term, the absence is Unjustified. A parent's note does not provide justification.	U	A
N	Not in class	On a school based activity	A school-based (on-site) activity: cultural/sporting presentation/practice including swimming/athletic sports one to one tuition either as tutor or tutored	P	P
O	Not in class	Attending an off-site school-organised activity such as trip/camp	A school-organised off-site activity including overseas school trip (sporting, cultural or academic) school camp	P	P
W	Not in class	Work experience	Student is working for a recognised employer as part of their course (Gateway is an example)	P	P
R	Not in class	Removed (temporarily) from regular class (internal school student solution)	This code is for students who for a time period had an arrangement for alternative supervision. This may be in the administration corridor or in another teacher's class, instead of the student's regular scheduled class	P	P
Z	Not in class	Secondary Tertiary Programme (including Trades Academies)	The student is participating in a part-time (off-site) approved Secondary Tertiary programme that includes Trades Academies. The school is not entitled to be funded.	P	P
O	Not in class	Justified Overseas	A student accompanying, or visiting a family member who is on an overseas posting. (Up to 15 weeks) Eg military or diplomatic.	O	A
A	Not in class	Attending a Teen Parent Unit	The student is not in class, is on the school roll but funded elsewhere	J	P
A	Not in class	Attending Alternative Education	The student is not in class, is on the school roll but funded elsewhere	P	P
V	Not in class	Attending an Activity centre	The student is not in class but in an approved environment for which the school is entitled to be funded	J	P
F	Not in class	Attending an off site course/class	The student is not in class but is on a legitimate off-site school-based course	P	P
H	Not in class	Attending a Health camp/Regional Health School/Residential School	The student is not in class but in an approved environment for which the school is entitled to be funded	J	P
C	Not in class	Involved in Justice Court proceedings	Under existing legislation this type of absence is deemed to be Present when calculating ½ day summaries	J	P
U	Not in class	Student is Stood down or Suspended	Student is Stood Down or suspended according to the conditions of Section 14 of the Education Act 1989 (This code is for the period of the stand down/suspension. It does not include the day the stand down was imposed)	J	A

Key	
Green	Present for half day calculations
Red	Unjustified absence
Blue	Justified absence

Code not used: B
 Rules for Truancy Codes:
 J = Justified Absence
 U = Unjustified Absence
 P = Present
 O = Overseas (justified)

School closures

A Board of Trustees can close the school (for instruction) for reasons including:

- an emergency (earthquake, flood, etc); or
- strike closure

It is usual that ½ days lost do not have to be made up, but schools should confirm this when informing their local Education Office of the closure. The School calendar should be adjusted in the SMS to show such days (or ½ days) as a non-school day and this means the students' attendance cannot be marked. If the school's SMS cannot make a ½ day adjustment in the calendar, then students should be marked J (justified absent). In the case of a strike closure, although the school is closed for instruction, the Secretary expects boards to consider providing supervision for those students who do turn up. Note that Boards have ongoing responsibility for the safety of students while under supervision at the school, whether or not the school is also open for instruction

Keeping the school open

Depending on the circumstances the Board, while not closing the school, may ask parents to keep children (of specific, or all year levels) at home where possible, but if they send them to school they will be supervised. If the school remains open then students not attending are J (justified absent) and those attending are P (present).

Effectiveness

The electronic recording of attendance has had some significant effect on educational policy.

1. It has become one of the benchmarks of a successful school.
2. It has resulted in an expansion of the definition of absence.

3. It has to some extent resulted in a manipulation of absence as a result of 1.
4. It has resulted in legislation punishing parents who take their children out of school in term time.

Attendance reports are collected via the annual government censuses or equivalent and published at least annually.

In educational institutions such as further and higher education where attendance is not mandatory, the above have become less prevalent although are still monitored for the purposes of student satisfaction, etc.

Previous empirical literature indicates that student performance is inversely correlated with absenteeism. Studies in the USA (Roby 2004; Marburger 2010) would suggest that that attendance policies do improve performance. The authors investigate the impact of enforcing an attendance policy on absenteeism and student performance. The evidence suggests that an enforced mandatory attendance policy significantly reduces absenteeism and improves exam performance.

Reporting

As well as public and government accountability attendance data can be used within the institution to improve teaching and learning.

Firstly it is important that the data is available in real time and secondly that it is available in a management information system (MIS) that enables it to be linked to other collected data.

There are a number of ways that attendance data can be used in this way.

Using alerts the institution can be alerted to absences almost as soon as they occur.

The Future

In addition to the so-called am-pm attendance at the institution, the use of lesson attendance has become more prevalent in recent years. This can look at patterns of attendance within the day as well as detecting students who register at the start

of the day and then do not participate in any lessons. In addition it can be used to look at attendance in specific subject areas and with particular tutors as well as against gender age, etc.

Real-time recording and reporting with preset alerts can be an enormous aid to preventing unauthorized absence, and it can also be used to better allocate resources and track student patterns.

Summary

The recording of attendance has developed from a manual mark at the start of each morning and afternoon to a sophisticated electronic system using a multitude of codes to describe the type of absence recorded.

The increase in the publication of attendance particularly as a result of its collection through pupil-level census resulted in attendance records becoming a key indicator to the performance of an institution. In addition the role of attendance in the inspection process also increases its importance within educational institutions.

The use of attendance to manage the resources and management of a school is however still lacking in sophistication and development.

The future is undoubtedly going to see an increase in the recording of attendance both as a result of improved recording techniques and the desire for more management information. Whether this will result in an increase in performance remains to be seen.

Cross-References

- [Data Mining for Educational Management](#)
- [E-Portfolio in Higher Education](#)
- [Support for School and Institutional Improvement and Accountability](#)

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Audience Response Systems

► [Clicker Interventions, Promoting Student Activity and Feedback at University Lectures](#)

Augmentative and Alternative Communication

► [Assisting People with Physical Disabilities Through Technology](#)

Augmented Intelligence in Education

► [Artificial Intelligence in Education](#)

Augmented Reality

► [Augmented Reality in Education, Scope of Use and Potential](#)

Augmented Reality and Its Use in Education

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Introduction

Educational content is increasingly being delivered through learning environments that are digital or technologically enhanced. One such technology-enhanced application is the evolving medium of augmented reality (AR), a technology that integrates interactive computer-generated data with the user's environment within a display interface. AR has the ability to enhance the real environment and perceptually enrich the user's experience, hence "augmented." This makes AR an enticing technology for educators to use as a tool since the real environment gets "annotated and informative" through the overlay of virtual objects in AR. Students construct new meaningful situational experiences with these augmented virtual objects that are brought to life in the backdrop of the real environment.

History of AR

The history of augmented reality spans over half a century. The term augmented reality was thought to be coined by former Boeing researcher Thomas Caudell who used this technology to assist in assembly of a jetliner in 1990 (Lee 2012). However, its first ever use was earlier in the 1960s, where Ivan Sutherland demonstrated simple wireframe drawings in real time via the first see-through head-mounted display (Lee 2012).

AR is used to display information that is beyond our senses which is used to guide us in the real world (Azuma 1997). Since the late 1990s, this ability attracted attention to utilize its potential and applicability in diverse fields

including commercial, maintenance, and education industries.

Virtual fixtures are one of the earliest functioning AR systems designed for the air force. A superimposed exoskeleton provides a guide to perform tasks from a remote space. In 1999, ARToolKit, an open-source software library for the creation of AR applications, became freely available to the public and revolutionized its accessibility (Azuma et al. 2001), thus allowing educators, trainers, and educational designers to be able to design AR objects and use them freely. This remains one of the most widely used libraries for current AR designs.

For training, the car manufacturer, Volkswagen, in 2013 started to use AR to assist their service technicians to foresee the repair process virtually on the physical vehicle. AR technology had remained in the purview of the corporate world; until in 2014, wearable AR devices for the public was made popular with the availability of Google Glass, thus making searchable information available “on the go” and contextualized to the perceived environment. Thereafter, AR applications have grown in leaps and bounds with AR and virtual reality (VR) investment reaching more than \$1.1 billion in terms of business importance.

Definition of AR

AR is defined as a technology that enables users to engage with virtual information augmented (usually superimposed) by computer-generated sensory input, e.g., graphics on the *live* direct or indirect view of a physical, real-world environment. This mediated immersion places digital resources throughout the real world, thus, augmenting the users’ experiences and interactions. Augmented reality is a subset of immersive technology that accounts for various computer-generated sensory information augmented onto the real world. Commonly, the sense augmented is usually sight but may be applied to other senses such as olfactory, haptic, and auditory.

AR is a system that possesses the following properties (Azuma et al. 2001):

1. Combines real and virtual objects in a real environment
2. Interactive and in real time
3. Registers (also aligns) real and virtual objects with each other

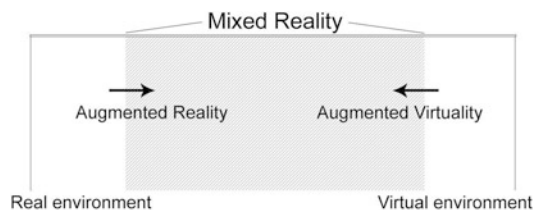
Thus to follow these criteria, not only do the virtual objects are to be placed in a real environment (e.g., as the virtual objects that were presented in the *Jurassic Park* movie) but also will these virtual objects need to be interactive to be considered as an AR (Azuma 1997).

AR belongs to one part of a spectrum of immersive technologies – the reality-virtuality continuum as illustrated by Milgram et al. (1994). At one end of the spectrum, as illustrated as the left side of the spectrum in Fig. 1 is the real environment – a physical space without any added virtual stimuli. At the other end is a world that is completely virtual with no involvement of physical elements.

The difference between augmented virtuality and AR is that it is more computer-mediated than AR as it adds real objects into virtual environment. Some examples of such real stimuli are such as texture mapping of videos onto virtual objects.

In the realm of AR, artificial intelligence is applied for its recognition of the “real world” to project the virtual information, thereby rendering virtual stimuli onto the real world and allowing user interaction. In contrast to VR, AR enables the user to experience real-life situations that are not readily or commonly accessible to the user (Rodriguez-Pardo et al. 2015).

Learning affordances of this form of mixed reality delivery of education include contextual skills development, tangible manipulation,



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Fig. 1 Diagram adapted from Milgram et al. (1994)

exploration, immersion, ubiquitous and situated learning, collaborative learning, reflection, analysis, and assessment.

AR Technology

The goal of AR is to integrate the computer's virtual object into the real environment or recognition of 3D virtual object space (objects, location, etc. within it) and so guiding the human user's visualization and knowledge of the same space. Because of this, AR requires enhancement of basic technology to create this complex integration. These enhancements are called enabling technologies, sensory interfaces, tracking system, registration of the virtual objects, and calibration to the environment (Azuma et al. 2001).

While various sensory interfaces such as auditory, haptic, and movement senses can be used, the interface most commonly in AR is visual displays such as head-mounted display, handheld display, or webcam-based displays. HMDs, which present a personal view of the AR environment, can be either optical or video displays. Optical displays are half-silvered mirrors with optical combiners to allow the augmented object to be seen in the real view of the user. Video displays on the other hand present a closed-view video that uses layering (chroma-keying) to augment the displayed video. These HMDs have their own advantages and disadvantages in terms of quality, immersion, and flexibility (Azuma 1997).

The commonest AR display devices are now handheld devices including mobile phones. The current high penetration of portable and mobile devices in the society particularly the younger audience makes ubiquitous learning and mobile learning with AR highly accessible to this crowd. Displays for AR are increasingly more powerful, compact, and portable making their availability more streamlined than before for wider user adoption (Lee 2012).

AR tracking can be designed as vision-based or sensor-based. Vision-based tracking can be further classified to *a priori* and *ad hoc*. An *a priori* system has prior knowledge of the object being tracked, and the most common example

of this as well as all types of tracking is marker-based tracking. Sensor-based tracking, on the other hand, utilises the GPS, magnetic compass, depth camera, inertia, infrared, or a combination of these technologies (Palmarini et al. 2018).

Use of AR Applications

AR is applied in a diverse range of fields and industries. The gaming market is one where it has found great success in. Some popular mobile applications include Pokémon Go; Temple Treasure Hunt; Zombie Go; Zombies, Run!; and Geocaching. These games have been instrumental in popularizing AR technology to the masses as well as introducing a large-scale social collaboration in AR.

In tourism, it can be used as a cultural heritage tour guide to display the view of the site prior to becoming ruins (Lee 2012). Museums can enhance the experience with viewing dinosaur fossils with augmented dinosaurs (Lee 2012). Art galleries use AR to display lost artwork.

The aviation industrial maintenance has used AR to reduce training time and error rates. An aviation maintenance inspector requires 2000 hours to become trained (Palmarini et al. 2018). The complexity of aircraft systems allows AR to be the preferred training method compared to traditional teaching. By reducing eye and head movements, allowing the user to skip the paper manual and concentrate the task at hand, AR reduces time and error rate in complex maintenance operations, thus improving profitability.

In sports, applications such as PoolLiveAid use AR to guide players in pool game with visual aids. It estimates the direction of where the ball will go and displays this in real time as the player can interactively adjust their aim to the visual cues.

AR is applied in the healthcare in a diverse range of fields including rehabilitation, physical medicine, psychology, psychotherapy, and mental health. AR's interactivity becomes an advantage when being used as a patient education tool. Weghorst as cited by Azuma et al. (2001) describes AR to rehabilitate people with Parkinson's disease suffering from an akinesia. In

the treatment of phobias, AR is used for subjects to transfer acquired skills in therapy to the real world (Riva et al. 2016).

AR in Education

By bridging the gap between the virtual and physical world, AR has revolutionized our conventional teaching methods. There are now many emerging applications of AR for use in digital classrooms. As an example of its use, Google Sky Map is a planetarium application to teach astronomy when viewing the night sky.

Of the various subjects and fields, AR is most commonly applied in the field of sciences at 40.6% (Bacca et al. 2014). Though the target group of most research on AR application is mostly students of bachelor's or equivalent level, various AR games have been successfully designed for school-going students.

Some examples of AR games for early years of learning include an AR system for K-12 students to learn means of transportation (Lee 2012), a virtual space in AR for learners to collaboratively construct geometric shapes for K-12 students to learning geometry (Lee 2012). In physics, AR objects with various kinematic properties were created for learning through their estimated visualized results in real time (Lee 2012).

An exciting application of AR is the concept of "magic books" where the information presented through books are integrated with AR. These are similar to the 3D pop-up book, but, instead of physical viewing and interaction, 3D models are rendered virtually in an AR display.

Numerous literatures on anatomy learning in AR have been published for target groups ranging from children to medical students. These applications typically superimpose organs onto the user's body or a friend's body. Similar to virtual museums with lost artwork, a repository of anatomy learning objects in the laboratory is designed as an AR museum for medical students to explore.

In the higher education sector, AR can be used to simulate field work and even work-based learning (WIL). For example, in the medical

field, clinical experience is highly regarded for medical and health professionals to form core competencies with the consideration of patient safety. A pilot work by the authors developed presentation of clinical signs in AR to facilitate physical examination (Sen et al. 2017). Preliminary data has shown potential in authentic learning of clinical skills without posing risks to patients. In spite of numerous published articles, AR's role as a supplementary method of delivery in education remains as a huge potential that needs to be explored further.

Potential Benefits of AR

For a generation of learners more technologically fluent than ever, AR holds great potential in enriching their learning. AR applications offer a very efficient method to deliver small bite-sized learning content for students. Such small chunks of content through AR can be used to explain a topic and augmenting information on a pre-existing learning topic (Bacca et al. 2014).

In educational research, AR has been the subject of study by educators for its impact on learner. Commonly studied measures to evaluate AR in education are learning gains, motivation, engagement, and collaboration. In general, most studies indicate improvement in learning outcomes. AR has been found to have positive effects on conceptual thinking, interaction with others, and cognitive load. Objectively, this was evidenced by a study that found improvement of performance (by 53.5%), motivation (by 28.1%), and engagement (by 15.6%) with use of AR (Bacca et al. 2014).

In another study, students learning about solar systems through AR were found to achieve greater scores compared to conventional learning methods. Similarly, students learning about parts of the aircraft turbine engine through AR showed improvement in short- and long-term retention of information. This was consistent with another study that used AR to teach word pictograms using more detailed information in comparison to desktop conditions. Compared to pre-existing level of achievement, learning gains in AR

learning modality were higher in low to average achieving students and thus had a more impact than on high achievers (Radu 2014).

Game-based learning increased the learner's engagement and significantly found greatest positive impact in less academically successful students (Lee 2012). Another study found that game-based learning promoted student collaboration in solving tasks in K-12 mathematics, language, and scientific literacy (Dunleavy et al. 2009).

Educational Theories in Relation to AR

Various theoretical underpinnings have been put forward to explain the impact of AR in education. One of them is the conceptual blending theory that describes how, in AR, the combination of virtual objects with real objects within a real space gives new meaning to the learner. In AR, the dynamic physical qualities of the visual presentation may become the focus of the learner's attention because of the learner's control over the content. Teaching children astronomy in different mediums found that children use different ways to conceptualize content. In AR, children learned to identify planets based on movements, while in PC presentation, children focused on details and visual look of the planets (Radu 2014).

Constructivism is a learning paradigm that encompasses an active, contextualized process of constructing rather than acquiring knowledge, based on personal experiences and the environment. Constructivism accounts for the learner playing an active role in connecting theory and application by interacting with the AR content that creates both an engaging personal experience as well as interactive environment. Being actively involved through AR can provide experiences in a novel way toward authentic (real-life) scientific inquiry (Zhu et al. 2014). Some examples are the "Alien Contact" AR project where students could act "like a real scientist" when solving situational puzzles and medical education AR applications where transfer of knowledge to real-life situations was achieved by learning the orientation of superimposed human organs even

if mistakes were made (Dunleavy et al. 2009; Radu 2014; Sen et al. 2018). The students found the experience with the AR environment to be a personalized and explorative experience for themselves (Zhu et al. 2014).

Reduced cognitive load may be an explanation of improved task performance. In repair and maintenance on military tanks, workers performed faster with fewer head movements (Radu 2014). Puzzles with AR instructions had faster completion time with fewer steps (Radu 2014). In healthcare training, AR decreased the amount of practice toward proficiency and reduced failure rates in real life (Zhu et al. 2014). In relation to Mayer's multimedia learning theory, this could be explained by the spatial and temporal contiguity effect. AR can present the information within the same plane in the real environment, while temporally, AR presents information closely with a physical phenomenon to allow an association to form (Radu 2014). This real-time interactivity has been found to provide a focused guide for users to learn more effectively (Riva et al. 2016).

Enhancing the learning experience with whole-body interaction using AR relates to the concept of "embodied cognition." "Embodied cognition" links the conceptual understanding of the abstract concept with physical activity such as gesturing or hand movements (Radu 2014). Inputs to the AR experience enhance skill proficiency in a range of motor skills, hand coordination, hand-eye coordination, fine motor, and gross motor (Radu and Macintyre 2012). The enhancement of the learning experience with tactile, audio, and visual cues is a form of multisensory integration.

In experiential learning theory, the shared experience from coordinating a mixed reality space with learners becomes meaningful to the student. When students perform such a shared activity such as navigating a map together in AR, students experienced more effective collaboration with greater retention and motivation in the learner (Radu 2014), a typical example of the experiential learning theory.

Affective reactions, such as enjoyment and pleasure, toward the immersive technology

support the “flow theory” (Suh and Prophet 2018). AR environments can create strong engagement between the narrative and real world. This may explain how unmotivated students transform to become highly engaged. Students can become willing to play the game repeatedly out of pleasure as they enjoy the challenge of graduated difficulty in these AR games (Dunleavy et al. 2009). This is driven by their internal goals as well as the balance between challenge and their goals (Radu 2014). Furthermore, some of the AR GPS-based games can allow students to express creativity and environment exploration. Higher enthusiasm in learners in turn produces higher satisfaction ratings.

Challenges in Using AR for Education

While the AR tools in creating an immersive educational experience are advancing rapidly with the betterment of technologies, there are still limitations of current AR technology. The development of AR content in AR involves both high cost and considerable time. Although open libraries (e.g., open CV, open GL, MATLAB) and software development kits (SDK) are freely available to facilitate its programming design, most of them are based upon mid-to-low-level programming languages (e.g., C++, C#, Java, HTML, CSS, etc.). These programming aids are not yet user-friendly for the public at large and still require highly skilled people to utilize them in creating AR systems.

AR applications for education are designed to enhance specific learning tasks and thus to customize to the educators needs; many of these well-designed AR applications still need to be created from scratch rather than through ready-made templates. Thus, the process still requires visual designers, 3D artist, and games/AR designers rather than it being in the purview of sole educator. Visual designers are also involved in designing presentation of the information within the AR applications. Some, though not all AR objects are 3D models superimposed on the real environment, and this 3D modelling requires skills in

design software applications such as Catia, Blender, and 3Ds Max; therefore, a 3D artist may be sought making the AR applications of good quality but expensive to produce. Creating AR-based games will also require collaboration with game designers (Palmarini et al. 2018). Due to its intricate development phase, direct access to author content is not yet accessible to educators (Bacca et al. 2014).

Creation of accurate realism of content is limited by current image capture technology. Video blending limits the user’s view to the capability of the cameras but may lack realism altogether (Azuma 1997). Human eye can adapt to six orders of magnitude of light, but brightness determines the eye pupil size which in turn also determines the depth of focus. Current display technologies like using the pinhole model show that all objects are in focus regardless of distance (Azuma 1997). Furthermore, displays may also adapt poorly to the real environment causing errors in depth perception (Azuma et al. 2001). In comparison, if the environment is too bright or dark, the virtual object is immediately identified as virtual. Accommodation-vergence conflicts in the eye, low resolution, and inaccurate lighting cause the virtual object to appear further away. Over time, users adapt to this displacement and exhibit large overshoot in real-life performance (Azuma et al. 2001). Further development in graphics is needed to simulate better match depth and real distances as in a human eye (Azuma 1997).

Other anticipated issues with AR are mostly related to technological failures. Time learning could be lost due to either GPS failure, software instability, or incorrect setup of the system. GPS failure could be as high as 30% which could be also complicated by environmental factors such as weather extremes that may prevent GPS-based outdoor-based AR activities (Dunleavy et al. 2009).

To avoid the challenges of GPS-based AR, majority of educational AR projects opt for marker-based AR for ease, stability, and less complex tracking. Furthermore, open libraries offer more readily available marker-based AR with more technical support (Bacca et al. 2014).

However, marker-based tracking suffers greatly from registration issues. The tracking algorithms depend heavily on the marker's position, orientation, and visibility which are frequently affected by weather and wear (Palmarini et al. 2018). Frequently, common tracking algorithms track poorly causing frustration to users (Bacca et al. 2014). It is challenging for input devices with low frame rates like webcams to depict quick gestures, thus resulting in interrupted interactions in AR (Radu and Macintyre 2012).

Registration error occurs when the system is unable to accurately track the desired object seamlessly. This triggers motion sickness to the user due to conflicts in the human senses. For example, a visual error occurs when the user perceives the virtual hand at the wrong distance over the real hand (Azuma 1997). Temporal latency also contributes to registration error. The interactive nature of the AR medium dictates that the system must respond to the user's unpredictable actions. Registration latency causes static and dynamic errors where objects remain still or move inappropriately (Azuma 1997). The augmented information is delayed resulting in reduction of task performance (Azuma et al. 2001).

Apart from the software issues as described above, there could be challenges in usage of the hardware. Hardware displaying AR can be the source of physical discomfort to the users. An example of this is the "tunnel vision" due to the limited field of view of some displays that may even aggravate motion sickness (Radu 2014). Such a limited field of view also interferes with team interaction and collaboration (Bacca et al. 2014). Prolonged exposure to display screens causes fatigue and eye strain to the user, also known as computer vision syndrome (Azuma et al. 2001). Repetitive strain injuries resulting from bending or sustaining postures for long periods of time also occur (Radu and Macintyre 2012).

Limitations in the hardware can also pose challenges in AR design. A study found that younger children would typically hold the device with both hands because the device is too heavy for one hand. This interrupts their live interaction in the session as they had to place it down before moving the markers. Some types of displays

also limit the physical space for exploration, counteracting benefits of gross motor training (Radu and Macintyre 2012).

Though AR applications appear to aid visualization, the use of AR systems and hardware can counterproductively increase cognitive load (mental activity exerted on the working memory). These systems are quite complex to set up, and configuration of the head-mounted display to the platform itself can be complicated and time-consuming (Radu 2014). An education session utilizing more than a single type of device to access the content also contributes to high cognitive load (Suh and Prophet 2018). Some students may become overwhelmed by the amount of AR content for use within a short time span (Dunleavy et al. 2009). High requirements of support and management from technical staff raise the question of how feasible AR curricula are on a large scale. Teachers, working independently in classroom situations, find it challenging to support and troubleshoot the technicalities of the AR activity without support from technical staff (Dunleavy et al. 2009). Despite these difficulties, students remain highly motivated to learn how to use the new technology (Radu 2014).

Distracted attention occurs when students ignore important parts of the learning task (Suh and Prophet 2018). Similar to how in assembly task training, workers tend to ignore previous errors and proceed to complete the task with poor recall of the errors made (Suh and Prophet 2018), in AR game-based learning, students may become focused on "winning the game" and ignore the steps in solving the problem, thus resorting to guessing or copying another person's answers to "win." This is also described as attention tunneling (Radu 2014).

Features of novel technology, such as AR can distract the students. An infrared function of an education session caused them to fail to complete the learning task (Bacca et al. 2014; Dunleavy et al. 2009). Distraction is also aggravated by teacher domination in the session (Suh and Prophet 2018). Limited number of displays also makes participation difficult, and students no longer pay attention to the session. In this way, the benefits of AR technology are no longer at

play because students are ignoring the real environment.

Distracted attention outside the classroom can be dangerous. Studies featuring GPS-based tracking found students too engrossed with the game space and lose awareness of the real environment (Suh and Prophet 2018). They were guided back to safety when wandering into traffic area (Dunleavy et al. 2009).

Studies found negative cognitive reactions to immersive technology and presumably, toward AR as well. Demographically, immersive technology is less well-received with the female gender and older age groups (Suh and Prophet 2018). Personal attributes like high sensation-seeking tendency and poor personal innovativeness also contribute to poor response to mixed reality technology (Suh and Prophet 2018).

In comparing AR with VR, AR has fewer graphic requirements because of fewer virtual objects to render. In addition, realism can be compromised in goals of AR; thus, high-quality graphics are not necessary. Lower-resolution and monochrome images can be used (Azuma 1997). For example, to outline a workflow, simple lines can be used to demonstrate the desired design.

In terms of tracking, AR requires a higher registration and representation fidelity (Suh and Prophet 2018). These errors are very easily detected in an AR environment. VR is more forgiving. This is because in VR, “visual capture” causes the user to eventually adapt to the systematic errors from prolonged exposure. While in AR, “visual capture” would not be beneficial in the goals of most AR applications as accuracy is key for translation of skills to the real world (Azuma 1997).

Future of AR in Education

It has been predicted that global research, education, and training by 2030 and beyond will witness a prime focus on the AR/VR industry and its applications. With the advent of social media having drastically changed how people interact with each other, its platforms are a potential avenue for

incorporation of learning with mixed reality (D’Angelo 2017). As technological advancement will overcome some technical difficulties highlighted earlier, AR will become not only more ingrained as part of everyday life and social platforms but will be more ubiquitous and more accessible to all (Suh and Prophet 2018).

With the markerless AR technology growing, development of new algorithms to identify forms can resolve major issues associated with markers (Bacca et al. 2014) which will make use of AR universal and not limited by connectivity. Trends show that new computer-aided design models can potentially overcome registration and tracking issues. By extracting features of the virtual object and comparing with the image of the real object, the real object is identified through the image being captured by the camera. This technology attempts to overcome lighting issues, one of the greatest challenges in AR technology (Palmarini et al. 2018).

Further research on AR in the field of education is on the cards. Research is focusing on novel technologies with computer vision and motion sensing capabilities that allow users to interact with the digital environment with greater immersion than before. For example, an interactive performance system for dance learning measures visual and sonic aspects of gestures by a system called action graph. This system enables mapping of gestures with desired augmented generation of functionalities, thus enhancing dance training interactively (Iqbal and Sidhu 2017).

Types of studies on AR are also expected to change. There is yet large-scale educator-led AR-based curricula in place. Larger study sample sizes will be possible once developer tools and AR hardware become more accessible. Further studies are still needed to identify curricular-specific and technology-specific characteristics that contribute to learning (Dunleavy et al. 2009).

Evaluation methods on impact of AR applications are presently mainly qualitative in nature and need to be diversified to include more quantitative measures on user experience (Suh and Prophet 2018). As AR is becoming more ubiquitous and no longer remains a novel educational tool, studies that compare AR with non-AR

delivery of education cross-sectionally need to extend their focus to longitudinal studies to identify long-term effects on learning once its novelty has worn off (Palmarini et al. 2018). Such research will help reveal the genuine positive learning impact of AR technology apart from its novelty effect.

There is a need for more studies of impact of AR application on diverse groups of students. Target groups of educational AR are mainly of students at tertiary level of education and of scientific backgrounds (Bacca et al. 2014). AR applications' ability to support learning should not be limited to those already in an educational institution. Further studies can provide more information on its applicability to other possible target groups in other fields such as vocational studies, art, language, psychology, and therapy (Suh and Prophet 2018). Another identified potential target group is the use of AR for special needs students (Bacca et al. 2014). Multimodal applications can be used as therapy for sensorial and physical impairment. VR has been found to be effective in aiding autistic people to cope in social situations (Riva et al. 2016). In mixed reality settings, AR can potentially create inclusive educational settings for people with special needs (Bacca et al. 2014).

Types of content suited for AR are being explored extensively to match the appropriateness of the content to the design of the AR. As an example, topics that rely heavily on abstract thinking may be difficult to be designed and taught via AR, while visual-based content may be more suited for AR delivery. Further studies are ongoing to measure the learning benefits of these identified types of content objectively. As raised by several studies, AR will likely be complement to education delivery not a substitute (Azuma 1997; Rodriguez-Pardo et al. 2015).

As discussed earlier, low-achieving students found greater learning gains with AR compared to high achievers. To be inclusive and benefit both ends of the student cohorts, further customization is needed to create content appropriate for a range of pre-existing level of achievement. The creation of tools for educators to author content and personalize to the learner's needs

is another facet that has yet to be addressed. Only a few (2 out of 32 studies) identified in a literature search found some personalization process (Bacca et al. 2014). Ideally, future research will identify the differences in learning gains when tailored to the audience's needs.

Social acceptance is an important factor to be studied to determine whether wider use of AR would be feasible (Azuma et al. 2001). For example, what society thinks of AR will affect how likely a user would wear a head-mounted device in a public area. As current applications are still in the prototype phase, data on market penetration remains to be fully gathered (Zhu et al. 2014). However, its acceptance will improve vastly as AR is gradually being integrated to everyday life and is being seen both as an educational tool as well as a platform for social interaction.

The application of AR in education has opened up new vistas in learning paradigm such that the current and future designs of AR in education may need guidance from learning theories. AR applications have opened up new possibilities than what the present traditional learning strategies can afford. Design guidelines for human-computer interactions exist and can be the building blocks for future AR design guidelines. These guidelines will also need to be field-specific (Zhu et al. 2014). Due to AR's nature of being highly hardware dependent, its applicability is being given due to the consideration to the learners' age group which may dictate the type of hardware used in its particular learning needs, especially, as previously discussed, where younger age group user struggle with handheld devices (Radu and Macintyre 2012). Identifying the limits of AR applicability is crucial for educators to select appropriate content to teach in AR. With considerations of current gap of research in AR, guidelines for effective designs of AR-based educational experiences can be proposed (Radu 2014; Bacca et al. 2014).

Conclusion

AR has been gaining ground since its first use almost 50 years ago. With its expanse of potential benefits, AR integration in education has been

evolving and increasingly widespread especially now that mobile platforms are so easily accessible. As an effective supplement of education delivery, AR has been found to increase visualization, interactivity, and knowledge content. Many beneficial AR factors on education have been identified though more detailed studies are needed to examine their long-term relationship to learning. In order for AR to reach its full potential in the field of education, further studies as well as technological advancements are necessary. It has been raised consistently that guidelines are needed to aid in the design of AR-based learning environments. Learning theories have been identified and require further application in the development of these guidelines.

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Augmented Reality in Education, Scope of Use and Potential

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Synonyms

Augmented reality; Education; Emerging technology; Information and communication technology; Innovation

Augmented Reality: Definition and Features

Augmented Reality: General Idea

Augmented reality is a technology that has gained popularity in recent years; it is often referred to in the subject literature as an emerging technology that has great potential for educational activities. This technology is based on the idea of applying an additional layer of digital information to images of real objects and locations in real time, thus complementing and extending them with new, additional elements that are valuable to the user (Azuma et al. 2001). The additional layer of information can contain text, images, videos, or other multimedia or interactive components that expand the view of the physical world with digital elements. The main features that distinguish augmented reality from other technologies include seamless blending of virtual and real elements into one environment, giving users the ability to interact with this environment in real time, and providing accurate 3D placement of virtual and real objects (Azuma et al. 2001). The aim is to provide the user with a visually attractive and cognitively rich information transmission of a hybrid nature that combines physical and digital environments (Barfield 2015). Augmented reality is already widely used commercially in business and entertainment, but it is also finding applications in the services of cultural institutions and more often in educational activities and their promotion.

Augmented Reality: Technical and Practical Conditions of Use

On the practical side, the use of augmented reality requires the use of a mobile device, usually a smartphone, tablet, or special goggles. The application of the digital layer to the physical environment of the user can take place in two main ways: based on geolocation options the mobile device sends information about the user's location to the application, and this information is compared to a database of digital objects assigned to this location (this is the principle of many augmented reality games or the popular Layar search engine), or with the use of special markers (so-called

beacons) that can be located in space and contain encoded information read by the mobile device's cameras, as is often used in custom applications created for a given company or institution (Geiger et al. 2014; Sato 2017). Digital information can be displayed in a "head-up" model that displays information directly in the user's line of sight, on transparent surfaces such as special glasses, or in the case of applications for pilots or drivers, on a vehicle's windscreen. This type of presentation has many benefits because it allows information to be received naturally, without the user having to look away and at the mobile device; this is especially important in applications designed for people who must simultaneously follow the physical environment and the hybrid environment of augmented reality. Digital information can also be displayed in a "head-down" model which displays information on a traditional mobile device such as smartphone or tablet; this is a popular solution due to the widespread availability of mobile devices and their ease of use (Smith et al. 2017).

In the context of the practical aspects of the application, attention should be paid to three things that can significantly influence the quality of the message provided through augmented reality. The first factor is the technical parameters of the mobile device on which the application is viewed. Smoothly combining the physical and digital realms requires the device to have sufficient memory capacity and a fast network connection. The functionality and user-friendliness of the application itself are also very important: the service must be intuitive, easy, and pleasant for the user so the information can be delivered effectively (Tsai et al. 2016). The third factor is the information and media literacy of the user: receiving information in hybrid environments such as augmented reality requires competence in the field of multimedia processing and the ability to understand cognitively rich messages, which may not be easy for everyone.

Augmented Reality Versus Virtual Reality: Similarities and Differences

The concept of augmented reality is often discussed in the subject literature alongside the topic of virtual reality, which may raise questions

about the similarities and differences between these technologies. As explained earlier, augmented reality is based on combining digital and physical environments; specifically, on the image of the real world, a digitally generated information layer is placed which enriches the general message with new and relevant elements. As a result, the user can see physical and digital objects and information at the same time. Virtual reality, on the other hand, is based on the idea of immersing the user in an artificial digitally generated world and cutting off external stimuli from the real world. The goal is to give the user the impression of being in a 3D world that may or may not resemble the real world (Kipper and Rampolla 2012). Virtual and augmented reality are therefore two different concepts that should not be confused, but they are often discussed together in the subject literature because of the popular concept of the so-called virtuality continuum that was described in the 1990s by P. Milgram and F. Kishino. These authors presented a scale in which at one end there is the real world, at the other end there is virtual reality, and between there is what is referred to as mixed reality, which includes augmented reality. Virtual and augmented reality are thus found together on the scale of the virtuality continuum; hence they are often discussed together. However, they differ from each other essentially: virtual reality is a completely artificial digital environment, whereas on the virtuality continuum scale, augmented reality is close to the world of physical objects (Milgram and Kishino 1994).

Augmented Reality in Education: Current Scope of Use

Augmented Reality in Early Education

Augmented reality, due to its multimedial and visually attractive character, is used at early stages of education to increase children's motivation and attract interest in learning. Augmented reality is practically used, among others, to teach children simple motor skills: for example, pointing, moving, or catching objects; coordination, memorization, recognition of colors and geometrical

shapes, simple language skills, information, and media literacy skills; as well as basic competences in various educational subjects such as mathematics, biology, or languages (Salvador-Herranz et al. 2013; Solano et al. 2017). According to G. Salvador-Herranz et al., using AR in the education of preschool children led to "students showing greater attention in class, accompanied by a notable interest in the subject being taught" (2013, p. 37). Augmented reality can also be used as an educational tool to help build ethical competences and awareness, such as responsibility in the field of pro-ecological behavior (Bodén et al. 2013), road safety rules (Lugmayr et al. 2018), as well as soft skills related to collaboration and working in teams.

To summarize, augmented reality can be used at the entry level of education to teach core physical, intellectual, and emotional competences and more specific knowledge in different educational subjects, as well as to build social competences, attitudes, and behaviors. The interactive and multimedial nature of the message and its visual attractiveness can help motivate children to learn and help them build early, positive experiences related to education.

Augmented Reality in Middle-Stage Education

At the middle stage of education, augmented reality is widely used in teaching various subjects, especially those that are stereotypically seen by students as difficult or tedious, such as mathematics, physics, chemistry, geography, or history (Cai et al. 2014; Estapa and Nadolny 2015). It increases their motivation to learn, improves memorizing processes, and increases the level of understanding of the given subject. Similarly, as in the case of primary education, at middle school, and high school levels, a beneficial effect of using augmented reality on educational processes can be observed. Evidence for this can be found in the results of research carried out by S. Cai, X. Wang, and F. K. Chiang, who showed that using augmented reality in teaching chemistry has a positive influence on chemistry education among middle school students, especially low-achieving ones (2014). Similar results can be found in a

paper by A. Estapa and L. Nadolny, according to whom the use of augmented reality in mathematics education clearly increases students' level of motivation to learn this subject (2015). It is worth noting that research is always conducted on a specific group of students and often shows that the influence of augmented reality differs between different groups (for instance, more able students vs. less able students) and different subjects, but generally it seems the use of augmented reality has a positive effect on students' learning experience and their motivation to study, which may translate into greater achievements in understanding and remembering a subject's content.

Augmented Reality in Higher Education

Augmented reality is widely used in many fields of higher education, in particular science, biology, chemistry, and medicine. It is a valuable tool for visualizing information that allows students to deal in an accessible way with complex models, projects, and layouts. This is particularly useful to students of physics, chemistry, architecture, or engineering as it allows them to visualize phenomena and/or design complicated systems (Akçayır et al. 2016); it is also useful in the fields of biology and medical sciences for memorizing large amounts of knowledge, for instance, to study human or animal anatomy (Moro et al. 2017). Some research showed a positive effect of the use of augmented reality on students' cognitive processes in the field of medicine. Research conducted by S. Küçük, S. Kapakin, and Y. Gökteş showed, for instance, that using an augmented reality application when studying anatomy reduces the cognitive load yet yields higher learning achievements (2016). This thesis can also be confirmed by research conducted by C. Moro et al. that showed the great effectiveness of virtual and augmented reality as tools for learning anatomy in the field of medicine; they provide an engaging, interactive environment for studying and increase students' motivation and enjoyment (2017). Analogous results have also been shown, among others, in research conducted with students of physics. M. Akçayır et al. showed that using an augmented reality app can significantly

help students to develop their laboratory skills, as well as to build positive attitudes toward physics laboratory classes (2016).

As in the case of learning at entry and middle levels, students can also use augmented reality to learn personal and social skills such as the ability to study effectively. According to research by J. Martín-Gutiérrez et al., augmented reality facilitates collaborative work among students and creates an environment for autonomous learning (2015). Augmented reality is used not only by students of science and medicine but also by students of humanities and social sciences, such as history, communication, linguistics, or art. Research conducted by J. A. Delello, R. R. McWhorter, and K. M. Camp on a group of students of marketing, human resource development, and education showed that for all three disciplines, augmented reality is a useful tool for learning that creates a positive experience for students and encourages them to learn (2015). The use of new information and communication technologies such as augmented reality may positively affect the motivation to learn, as well as support students' creativity, the ability to understand cause-and-effect processes, as well as develop empathy and other moral values.

Augmented Reality in Adult Education

Nowadays, education lasts a lifetime, and many adult people who are professionally active want or need to continually improve their education. Augmented reality can also be applied to work-related adult education, for instance, during training or courses. Analogously, as in the stages of education discussed previously, in adult education augmented reality can be used both to build specific professional skills characteristic of different professions, as well as to build general personal and social competences, such as group work skills, work planning, and time management, and to increase motivation to work. Augmented reality is used, among others, in applications supporting the repair of vehicles by mechanics or in applications for professional drivers, pilots, engineers, architects, and designers. There are not many papers exploring this topic; however, based

on the promising results of studies from the higher education sector, it can be assumed that augmented reality may also be useful in processes of lifelong learning and self-improvement of adult learners.

Augmented Reality in Special Education

A very important aspect of the usefulness of augmented reality is its use in the education of people with various types of disabilities, most often emotional, intellectual, cognitive, and sometimes also physical (Richard et al. 2007). There is a lot of research related particularly to the usefulness of augmented reality in the education of people (especially children) with Asperger syndrome and autism at various stages (Escobedo et al. 2014; Nazaruddin and Efendi 2018; Syahputra et al. 2018). Research has shown that augmented reality can help people with autism spectrum disorder (ASD) to better focus on tasks, which is crucial for knowledge acquisition processes in various disciplines. Augmented reality can also be helpful in the process of developing social skills, such as understanding situational contexts or recognizing body language and emotions (Escobedo et al. 2014; Syahputra et al. 2018). Research conducted by C. Chen, I. Lee, and L. Lin clearly showed, for instance, that “through repeated ARSFM training, adolescents with ASD can more accurately recognize and more appropriately respond to the emotional facial expressions they see in everyday social situations. This augmented experience can increase the ability of people with ASD to understand others’ emotions and improve the assessments of emotional expression and social skills of adolescents with ASD” (2015, p. 402). Augmented reality can also help in recognizing objects (Nazaruddin and Efendi 2018), which can be useful in learning many subjects that require the manipulation of shapes and their location in space, including mathematics and physics. All in all, augmented reality can be used in the education of people with special needs as a tool to help them focus attention, better understand models and spatial relations of objects, and increase general social skills, as well as motivation to learn.

Main Areas of Augmented Reality Use in Education: Summary

Summing up, it can be concluded that augmented reality is used at various degrees of the education of children, teens, adults, and those with disabilities, to support the development of various groups of competences in science, medicine, humanities, and social sciences. The subject literature analysis shows that augmented reality may help in the development of spatial imagination, visualization and understanding of models, decision-making skills, critical thinking, and understanding of processes (including social and historical). Augmented reality also helps in the formation of language skills (particularly foreign language learning), the ability to discuss and work in groups, as well as in the development of general imagination and creativity (Wójcik 2016). Importantly, using augmented reality in the process of learning often increases students’ enjoyment, satisfaction, and motivation in the subject being taught. As J. Bacca et al. conclude, augmented reality is particularly effective as a tool for “better learning performance, learning motivation, student engagement and positive attitudes” (2014, p. 146). Of course, not all research results clearly show a high-quality difference in teaching with the aid of augmented reality. Bearing in mind that many factors contribute to the final effect of education, in the process of assessing the influence of augmented reality on education, it is important to take into consideration the target group, the subject being taught, the teacher’s competence, and the quality of the application itself. However, it seems that the majority of studies show the great utility of augmented reality for teaching and learning.

Augmented Reality in Education: Benefits and Risks

There is no doubt that the use of augmented reality in education has many advantages. First of all, it is an innovative technology that can be used to transfer knowledge in a new, attractive way that increases motivation to learn and helps build

positive learning experiences. The engaging and visually appealing multimedial character of the message arouses interest and willingness to learn in both children and adults. As has been shown, augmented reality may increase the effectiveness of education in many fields and at different levels of education, including the education of people who are struggling with intellectual, emotional, or cognitive problems. However, as with any innovation, there are certain dangers that must be remembered. Some authors conducting research in pedagogical sciences and psychology point out that cognitively rich environments such as augmented reality can overwhelm the user and cause feelings of confusion, stress, impatience, or information overload (Wu et al. 2013; Bower et al. 2014). According to Wu et al., “There are also challenges related to learners and their learning processes. In an AR learning environment, students could be cognitively overloaded by the large amount of information they encounter, the multiple technological devices they are required to use, and the complex tasks they have to accomplish” (2013, p. 47). As Bower et al. conclude, “(…) utilization of technology is by no means a guarantee of success. On the contrary, poor use of emerging technology can result in inferior learning outcomes” (2014, p. 12). The use of augmented reality in itself does not bring educational benefits but only serves as a tool for achieving didactic goals and must be used correctly in order to tap potential and minimize risk. One often-mentioned risk factor is the need for users of augmented reality to have specific competencies that enable effective use of this technology. The use of applications based on augmented reality requires, for instance, a specific level of technical knowledge that enables smooth operation of mobile devices and apps. A systematic review of the subject literature conducted by M. Akçayır and G. Akçayır showed, for instance, that some of the biggest challenges that may discourage students when using augmented reality in the classroom are related to technical problems and the usability of applications (2017). For the effective implementation of augmented reality, it is therefore necessary to have good quality electronic equipment, well-designed applications, and

the competences for their proper use on the part of students and teachers. In addition to technical competences, it is also very important to take into consideration students’ level of competences in the field of information and media literacy. The ability to selectively receive information shared in cognitively rich environments is necessary to fully benefit from the potential of augmented reality. These competences should ideally be represented among students, teachers, and parents but at least among teachers so they can assist students. This is especially important when working with the intellectually, emotionally, or cognitively disabled, as was pointed out, among others, by M. A. Nazaruddin and M. Efendi in the context of using augmented reality applications to teach people with autism (2018).

The use of new information and communication tools in educational processes is often also hindered by practical problems related to the need to purchase appropriate equipment and applications, which can be expensive when providing for large groups of students. Using augmented reality applications also requires constant updating of equipment and teachers’ knowledge in the form of training, all of which can be very expensive. The downside of using augmented reality in education is therefore the need to incur regular financial expenses which may be beyond the financial capacity of many schools.

Summing up, it can be concluded that using augmented reality as an educational tool has both pros and cons. The risks and negative aspects of using this technology can mostly be neutralized by rational planning of the role of new technologies in the educational process and costs related to their use, as well as by equipping students and teachers with the competences necessary for the effective and responsible use of augmented reality.

Augmented Reality in Education: Potential for the Future

The positive effect of using augmented reality on the teaching of competences has been proven in many areas, but many have not yet been

examined, and, as emphasized by Wu et al., in comparison with research on the use of other tools in education, for example, the Internet or multimedia, research on the effectiveness of the application of augmented reality is still in the early stages (Wu et al. 2013). Augmented reality is, however, mentioned in many publications by both scientists and practitioners in various fields as a so-called emerging technology that will develop and become more and more popular in the future (Bacca et al. 2014; Ponce et al. 2014; Ozdamli and Hursen 2017). According to F. Ozdamli and C. Hursen, “Augmented Reality is a developing technology which has the potential to influence the teaching–learning process” (2017, p. 122). A similar opinion is presented in a paper by C. S. C. Dalim et al., according to whom “Integrating AR in education may lead to a brighter future for the educational sector. AR has the potential to engage students in a better learning experience that could create a more comprehensive teaching and learning process” (2017, p. 586). Based on these predictions, it seems that incorporating augmented reality into educational processes is a wise decision; however, much depends on the level of acceptance of this technology by students, parents, and teachers. Research carried out so far in this area is rather promising. A study conducted by A. Balog and C. Pribeanu showed that the perceived usefulness and enjoyment of using augmented reality tools in education are factors which greatly affect the level of acceptance of this technology among students (2010). C. S. C. Dalim et al. identified six factors that influence the acceptance of augmented reality: the balance between the technical and pedagogical aspects of an augmented reality application; the reliability of an augmented reality app; a student’s ability to use augmented reality independently without help from teacher or parent; the ability to include others in the process; students’ individual features and background; and the platform used to deliver augmented reality (2017). Knowing the factors that influence the adoption of new technologies can facilitate their widespread introduction and encourage the belief that augmented reality may have great potential for educational activities in the future.

Conclusions

Augmented reality is already widely used in various stages of education, in different age groups, and to shape various competences. The cited studies show the possibilities of the effective application of augmented reality in the education of children, adolescents, and adults in many areas: history, geography, biology, medicine, mathematics, physics and chemistry, languages, motor and spatial skills, object recognition and coordination, and social competences such as working in groups or autonomous learning. Importantly, many studies indicate that the use of augmented reality not only increases the efficiency of learning specific knowledge or competences but also increases students’ satisfaction and motivation to learn, all of which helps to create a positive educational experience.

In summary, it can be said that augmented reality is applicable everywhere that it is important to visualize complex processes, procedures, or objects or to increase students’ level of motivation and enjoyment when learning subjects often considered difficult or tedious. Augmented reality’s full range of applications in education is not yet known, but it seems that this technology has great potential. However, as with any innovation, it is important to maintain a reasonable approach and implement new solutions gradually to avoid possible negative effects that often accompany the use of technology in education, such as cognitive stress or information overload.

Cross-References

- ▶ [Assisting People with Physical Disabilities through Technology](#)
- ▶ [ICT-Based Inclusive Education](#)
- ▶ [Implementation of ICT in Secondary Schools](#)
- ▶ [Literacy and Technology](#)
- ▶ [Mobile Computing and Mobile Learning](#)
- ▶ [Mobile Learning](#)
- ▶ [Students’ Computer Literacy and the Use of Tablets in Upper Secondary Schools](#)
- ▶ [Tablet Use in Higher Education](#)
- ▶ [Technology Enhanced Learning](#)

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Automated Assessment Tools

► [Technology-Enhanced Learning in Programming Courses, Role of](#)

Autonomous Learning

► [Digital Literacy, Creativity, and Autonomous Learning](#)

B

Beginnings of Computing in School Education in Australia

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Synonyms

Computer science; Information technology;
Primary schools; Secondary schools

Introduction

In the early 1970s, a small number Australian schools began to get involved in computing, typically resulting from the exposure of maths/science teachers to computing during their university courses. The way computing was typically introduced was through the teaching of programming by the school's mathematics department. Early examples included a PDP-8 computer in one Victorian secondary school and an 8 k Wang computer in another, each paid for through a Commonwealth Schools Commission "Innovations Grant." The schools used teletype terminals with paper tape readers and accessed the computers via dedicated telephone lines. This arrangement was, however, soon seen to be not very satisfactory.

The next step was in 1974 with the introduction of MONECS (Monash Educational

Computer System) that typically ran on a DEC PDP-11 (DEAMON) minicomputer and used mark-sense cards for program and data entry (Monash Computing Museum 2003). This technology was also typically used in schools' mathematics departments for the teaching of programming in FORTRAN or BASIC. The students filled in the cards at their school using a pencil, and then their teacher delivered a batch of the cards to a local university for execution. The results were often disappointing for the students as in many cases all they got back was a printout listing a number of syntax errors. It took some students several tries to get a program working properly.

This then had very little overall impact on school education. It was the arrival of the microcomputer, and especially the Apple II in 1977, that saw the beginnings of real advance in the use of computers in education.

The Arrival of the Microcomputer

The late 1970s and early 1980s saw a huge increase in the number of low-cost microcomputers on the market and available to schools. These microcomputers included Apple II, Tandy TRS-80, Commodore VIC-20, Commodore-64, Acorn BBC, MicroBee, Atari 400/800, Cromenco, Osborne, Sinclair ZX80, XZ81 and Spectrum, Sorcerer, Altos, Franklin ACE, DEC Rainbow, Hitachi Peach, SEGA,

The Usual Procedure for Loading Tapes

1. Make sure your computer is in Applesoft BASIC
2. Rewind the tape
3. Start the tape playing
4. Type LOAD
 After you press RETURN the cursor will disappear. Nothing happens for from five to twenty seconds, and then the Apple beeps. This means that the tape's information has started to go into the computer. After some more time (depending on how much information is on the tape, but usually less than a few minutes) the Apple beeps again and the prompt character and the cursor reappear.
- 4a. If you got an error message such as ERR , the tape did not LOAD properly. Turn your computer off (with the switch in the back), and begin the process again at step one.
 NOTE: You cannot recover from a LOAD error by using RESET.
5. Stop the tape recorder and rewind the tape. The information has been transferred, and you are finished with the tape recorder for the time being.

Enjoy your new Apple!

Beginnings of Computing in School Education in Australia, Fig. 1 Loading tapes (Apple Computer Inc. 1979a)

Amstrad, Spectravideo, Apricot, Micromation, Pulsar, and Olivetti.

Of these, the Apple II, Commodore-64, Acorn BBC, and MicroBee became the most commonly used in Australian schools. These were relatively low-cost computers. At around \$2,000 for a 16 k Apple II that used a tape drive (not supplied – you had to use your own cassette recorder) and a television set (you also had to supply your own) as a monitor, the Apple II was almost affordable for most schools.

The IBM PC and Apple Macintosh did not appear in Australian schools until the mid-1980s. This made the need for some form of computer systems evaluation by state computer authorities most important (Tatnall and Jenner 1986). Australia is a federation of states, each having a considerable degree of independence. In education, the role of the Commonwealth Government is limited to one of coordination, leadership, and the funding of specific projects. School education is the direct responsibility of the states.

It is interesting to look at a page from the instruction booklet that came with a demonstration tape for an Apple II in 1979 to see what a

person taking delivery of their first computer might need to deal with (Tatnall and Davey 2008) (Fig. 1).

Later that year the first disk drives appeared, and a Word Processor program could be obtained from Apple. Advice from the instruction booklet (Fig. 2 below) was all in friendly caps (as most printers did not then have lowercase):

Once this “simple” procedure was undertaken, the instructions assure the user that *almost nothing could go wrong* with the program except if they had done something silly like pressing the Reset Key or typing in “too many lines” (see Fig. 3 below).

Computer Awareness and Other Uses in Secondary Schools

Once a school had purchased a computer, the question was what would you do with it? The obvious answer was to teach programming, but another idea that was to emerge was teaching a “Computer Awareness” subject. In Victoria in 1980, the McDougall report to the Education

RUNNING UP THE SYSTEM

AFTER SWITCH ON AND AFTER INSERTING THE WORD PROCESSOR DISK IN THE DISK DRIVE, TYPE 'G'; THEN HOLD DOWN THE 'CTRL' KEY WHILE PRESSING 'P'; THEN PRESS 'RETURN'.

WHEN THE DISK HAS STOPPED RUNNING THE SCREEN WILL DISPLAY AN INTRODUCTORY MESSAGE. TO CONTINUE WITH THE PROGRAM PRESS ANY KEY.

Beginnings of Computing in School Education in Australia, Fig. 2 Word Processor disk instructions (Apple Computer Inc. 1979b)

WHEN YOU HAVE FINISHED WHAT YOU WANT TO TYPE IN, YOU CAN TYPE 'END' AT THE BEGINNING OF A LINE. ON PRESSING 'RETURN' YOU WILL BE PRESENTED WITH A 'TRAFFIC DIRECTORY' TO HELP YOU CHOOSE WHAT YOU WANT THE PROGRAMME TO DO NEXT.

PLEASE NOTE –

IF SOMETHING GOES WRONG WITH THE SYSTEM DURING THE TIME YOU ARE ENTERING TEXT, IN MOST CASES THE PROGRAMME WILL RESCUE YOU FROM DISASTER. VERY RARELY, THE SYSTEM WILL GO HAYWIRE AND YOU WILL BE PRESENTED WITH AN ASTERIX (*) AND A SERIES OF UNINTELLIGIBLE NUMBERS. THIS IS DISASTER INDEED. YOU WILL HAVE TO START ALL OVER AGAIN. FORTUNATELY THE OCCURRENCE IS RARE. THE MOST USUAL CAUSE IS THAT YOU HAVE PRESSED THE 'RESET' BUTTON. USUALLY YOU WILL BE RESCUED. THE CAUSES OF THE PROBLEM ARE THESE –

1. YOU HAVE RUN OUT OF MEMORY,
2. YOU HAVE TYPED IN TOO MANY LINES.

IF YOU HAVE RUN OUT OF MEMORY OR HAVE TYPED TOO MANY LINES, SAVE THE FILE AT ONCE. YOU CAN BREAK IT INTO PAGES AND JOIN IT UP WITH OTHER FILES LATER. THE MAXIMUM NUMBER OF CHARACTERS IS ABOUT 12,000 AND THE MAXIMUM NUMBER OF LINES IS 200.

Beginnings of Computing in School Education in Australia, Fig. 3 Word Processor instructions (Apple Computer Inc. 1979b)

Department Computer Policy Committee noted that: “Computers have been called electronic ‘brains’ and there is no doubt that in the popular view, they are surrounded by an aura of mystery and are credited with powers they do not possess. The result is that most people outside the computing profession have attitudes of awe and fear towards computers and feel helpless and powerless in a highly computerised society” (McDougall 1980: 3). There is, of course, now no need to make students *aware* of computers and what they can do, but at this time computers were an unknown novelty. A typical Computer Awareness subject taught in a secondary school might include discussion of:

- How a computer works, computer programming, history of computer technology
- Business and commercial uses of information technology
- The social implications of increased use of computers

Subjects like this made use of the school computer (often an Apple II) to give the students some hands-on experience and quickly became popular with the students who were intrigued by the new computer. It was also seen as worthwhile by their parents, many of whom saw the possibility of better jobs for their children if they learned how to use these new machines. These subjects remained

in place in many schools until the late 1980s (Computer Studies Curriculum Committee 1983; Tatnall and Davey 2006).

It was not long before several different streams of Computer Education emerged in Australian schools:

- Computers across the curriculum – computer use in different subject areas
- Computer Science
- Programming in mathematics
- Use of Word Processors by secretarial studies students
- Logo
- Computer industry/business training in technical schools (Tatnall and Davey 2004)

State Computer Education Centers

In its 1983 report “*Teaching Learning and Computers*,” the Commonwealth Schools Commission (1983) sums up the early formation of computer education centers in Australia:

Education Departments in some states introduced computing into their schools before microcomputers became plentiful and inexpensive, by installing a minicomputer in a central place and using it to provide a service to schools. Having made this decision it was essential that a Centre be established with staff to operate the computer and provide support to teachers who were using it.

This comment refers in particular to South Australia and Tasmania which commenced programs of Computer Education (mainly of computer programming) earlier than the other states.

The South Australian Education Department had a policy on School Computing Activities which indicated that: “computing is an object of study in its own right, computing provides the means of enhancing and extending traditional components of the school curriculum and computing and related technology have the potential to change the curriculum, the manner in which that curriculum is implemented and to improve the general organisational procedures used by schools” (Shears and Dale 1983). In 1968 it sets

up the Angle Park Computing Centre which provided schools with a batch card-input system for teaching computer programming. It also produced curriculum materials and educational software.

Tasmania introduced a Year 12 Computer Studies course in 1972 and developed a state-wide time-sharing network for educational purposes. In the mid-1970s, it sets up the Elizabeth Computer Centre to develop educational and administrative software for the network and for microcomputers and the provision of advice and training to Tasmanian teachers.

The other Australian states and territories all got seriously involved in Computer Education after the intervention of the Commonwealth Schools Commission.

Assistance from the Commonwealth Schools Commission

In 1983 the Australian Government sets up the *Commonwealth Schools Commission National Advisory Committee on Computers in Schools (NACCS)*, to provide leadership and funding for Computer Education across all Australian states and territories (Tatnall and Davey 2008). “The widespread availability of a variety of hardware has opened up opportunities for school use of computing that have not previously existed” (Commonwealth Schools Commission 1983). In the period 1984–1986, the *Commonwealth Schools’ Commission Computer Education Program* provided \$18.7 million for coordination of Computer Education facilities and financial offerings in each of the states. The NACCS report *Teaching, Learning and Computers* listed a number of possible uses for computers in schools:

- Computer Awareness/Computer Literacy courses in upper primary and lower secondary schools
- Computer Science/Computer Studies/Information Processing
- Using computers across the curriculum
- Curriculum support including preparation of teaching materials and student records

- Communications with other teachers, students, and remote databases
- Administrative applications for database management and financial management

Computer Education Consultancy

An important school curriculum support mechanism used by many states in the late 1970s and 1980s was the Subject Consultant. These consultants were practicing school teachers who were seconded, usually on a part-time basis, and were chosen for their subject expertise, teaching ability, willingness to adapt to and lead educational change, and ability to get on with and work with other teachers. Unlike most other subject consultants, Computer Education Consultants were pioneering a new area of education and had little in the way of established precedent, techniques, or materials to assist them (Tatnall and Davey 2008). The task of the Computer Education Consultants was thus to introduce and offer suggestions on the use of computers in schools. They would run professional development activities, demonstrate educational software and discuss its possible classroom use, consult with individual teachers and school principals, and investigate possible school administrative computer applications (Tatnall and Davey 2012).

State Recommendations of School Computer Systems

The late 1970s and early 1980s saw a huge increase in the number of low-cost microcomputers on the market and available to schools. There was no way that each state computer education center could offer support for such a large range of computers, and so some recommendation and control process were necessary (Tatnall and Jenner 1986). In each state computer education center, a process of evaluating computer systems (both hardware and software) for educational use was undertaken regularly, and as a result, a “Recommended List” was set up, and

government schools were obliged to purchase only *recommended systems* with Education Department funds.

In 1985 in Victoria, the recommended computer systems were Apple IIe, Apple Macintosh, BBC Master 128, BBC model B, MicroBee, IBM JX, and Pulsar and in NSW, MicroBee, Apple IIe and Macintosh, BBC model B, IBM JX, Tandy 1000, and Sperry PC. In other states and territories, Apple IIe, BBC model B, MicroBee, and Commodore-64 were common recommendations.

The Australian Educational Computer

A longer-term proposal by NACCS was for the development of an “Australian Educational Computer” that would reinforce Australian culture with Australian software and be built in Australia by an Australian company. Several other countries including the UK, New Zealand, Sweden, and Canada had already decided to design and build their own school computers, and it seemed worthwhile for Australia to also do so. There were several reasons for a project to develop a computer of this type in Australia (Tatnall 2013):

- So that Australian school children would have access to well-designed computer equipment.
- To reduce the problem that US-designed computers such as the Apple II and Commodore-64 came with the burden of imposing aspects of American culture.
- To provide a development and manufacturing opportunity for Australian industry. It was generally supposed that an Australian company such as MicroBee, which produced a CP/M computer used in many Australian schools, would be a likely manufacturer.

To begin the project, NACCS sets up working parties for an **Educational User Requirement** and an **Educational Technical Requirement** to develop the computer. The Department of Science and Technology would then have produced a **Systems Concept Study** and **Australian**

Design Specifications (Commonwealth Schools Commission 1983), but at this stage the project stopped (Tatnall 2013, 2014). The 3-year government initiative for the National Computer Education Project was at an end and so was its funding. Perhaps it was a good thing that the project to build the Australian Educational Computer did not continue, as at this time the dominance of the IBM PC and the Apple Macintosh began. Had the project continued it may have created a white elephant like the ICON from Canada that was compatible with neither the PC nor the Apple Macintosh. Today the decision Australian schools make in choosing which type of computer to use is between a Windows PC and a Macintosh.

Computing in Australian Schools in the 1980s

In 1981 Computer Science was first offered as a Year-12 subject in Victoria. Most other states then also began offering Computer Science courses, typically in the last 2 years of secondary school. Computer Science courses usually involved the study of algorithms, programming in a language like Pascal, and understanding a little of the machines that carry out these procedures. They also offered some discussion of computer use and the social implications of computer use.

By the mid-1980s, uses of school computers for other than teaching programming were widely acknowledged, and computers were now beginning to be also used in other subject areas. The firsts of these subject areas were mathematics and commerce. There was some use of computer-based simulations in general science and of databases in other subjects including social science. Australian schools never did go very far down the line of Computer-Assisted Instruction (CAI).

One important application, especially in some primary schools, was the use of the programming language Logo that involved using commands like FORWARD 10 and RIGHT 90 to move a “turtle” around the screen. (Logo could be used for other programming tasks and was related to

Lisp) This was made more interesting to students by the use of a “turtle robot” that could be made to move around the floor. These robots were available from a number of overseas companies, but the one most used in Australia was the locally built “Tasman Turtle.” In the late 1980s and early 1990s, Lego produced a robotics kit, Lego Technics Control, that made use of a programming language rather like Logo and was used in some schools.

The use of computers for educational administration in schools began to grow from the mid-1980s. This typically began by local school teachers writing programs for things like managing the school sports and later programs to produce student reports and record attendance. By the mid-1980s, state education authorities began producing their own administrative packages to manage school finances and facilitate school reporting.

By the late 1980s, the teaching of secretarial studies moved to use of word processing programs, and commerce teachers began making serious use of spreadsheets. Despite being involved at the beginning, computer use by maths teachers was now in decline. At this time, with the relatively small number of computers in each school, conflict arose on how best they could be used. The conflict was between those who thought that teaching *about* computing was important and those who thought that only the *use* of computers in subject areas in schools was worthwhile.

Computing in Australian Schools from the 1990s to Today

By the late 1980s and into the 1990s, the large variety of microcomputers had vanished, and the PC and the Macintosh had been taking over.

The use of email began to grow rapidly in the late 1980s, and with the arrival of the World Wide Web in the 1990s, schools began to make use of the Internet (which earlier was text-based and quite difficult to use in schools) skyrocketed. Schools quickly found plenty of uses for this technology in many applications.

In recent times perhaps the biggest change has been the availability of mobile computing through the use of mobile phones and tablet computers such as the iPad. Some primary schools now proscribe the purchase of iPads by students in Grade 3 to use both at school and at home.

One of the latest developments is the teaching of “coding” which is claimed to assist with “computational thinking” that is seen as “a fundamental set of skills that all students need to be prepared for the future real-world challenges.” A Lego kit encourages the use of coding using its building bricks with the intention to “encourage students to explore, build, code, test and refine solutions to engaging STEM (Science, technology, engineering, and mathematics) challenges”(Lego Education 2016). Scratch (from MIT Media Lab) is also used in a similar way by some schools.

Conclusion

In the 1980s Computer Education was seen in the category of a *special* curriculum area. Its removal in the 1990s to become a normal part of the school curriculum reflected its coming of age. Far from being the novelty as it was in the 1970s, the use of computers in all types of schools for all types of applications is now commonplace.

Cross-References

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Big Data

- [Data Science Education](#)

Big Data in Education

► [Educational Assessment, Educational Data Mining, and Learning Analytics](#)

Big Five Personality Traits

► [Innate Abilities and Learning in Higher Education](#)

Birth of Information Systems Curricula in Victoria in Colleges of Advanced Education and Universities

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Synonyms

[Business computing](#); [Computer science](#); [Information technology](#); [University courses](#)

Introduction

Eighty years ago there were no stored-program electronic digital computers in the world. Even 50 years ago, a computer was something that few organizations could afford and few people could use. Suddenly, in the 1960s and 1970s, everything changed and computers began to become accessible. This created a big need for education in different forms of computing. Today the need for education in Information Systems (sometimes called Business Computing) is generally acknowledged with each university in Australia offering courses of this type. What happened to promote the adoption of such courses in Victoria is the subject of this article.

The first real electronic computers were built in the 1940s by engineers and scientists for military

and research purposes. In designing machines like ENIAC in the USA and Colossus in Britain, little heed was paid to possible commercial applications: it was during World War II, and the need was military and pressing. A major purpose behind the design of ENIAC was to solve the differential equations required for the calculation of ballistic trajectories. At the same time in England, Alan Turing, a pioneer in the theoretical foundations of computing, worked on Colossus, a special purpose computer adapted toward Boolean logic and designed for the task of breaking enemy codes (Winston 1986).

Early Computing in Australia

There are today two main approaches to the teaching of computing at the university level: those of *Computer Science* and of *Information Systems* (or *Business Computing*). But apart from both being based on the study of a particular machine, how are such courses related? It is tempting to think that perhaps as Computer Science came first, courses in Information Systems evolved from these as the *applied* version of computing. A study of the origin of computing courses, however, shows that this was not the case and that courses in Information Systems in Australia had origins quite different from those of Computer Science.

Australia made its move into electronic digital computing quite early. Trevor Pearcey and Maston Beard built the CSIR Mk1 (CSIRAC) in the late 1940s for the Commonwealth Scientific and Industrial Research Organisation (CSIRO). It was Australia's first internally stored-program computer and the world's fourth. From 1948 to 1956, it was located in the University of Sydney. In 1956 it was moved to Melbourne and set up at the CSIRO Division of Radiophysics in the University of Melbourne where it remained in service until 1964 (Pearcey 1988).

It had now become quite clear that it was necessary to create university courses in computing. The fact that it was the CSIRO, with its connections to the universities and to government, that led the way into computing in Australia

probably assisted in the early introduction of computing courses in Australian universities. Trevor Pearcey, prominent in building CSIRAC, joined the CSIRO Division of Radiophysics in Sydney at the end of 1945 where he worked for some years. In 1947, during his time at Sydney University in the Department of Mathematics, he introduced what was Australia's first university course in computing: *The Theory of Computation, Computing Practices, and the Theory of Programming*. This course was an early one and was offered before CSIRAC became operational in 1948 (Tatnall 1993).

Early Computer Science Courses

From the mid-1950s onward, a number of university computer systems were opened to general use, and practical training in programming and the application of computers was introduced at the Universities of Melbourne, Sydney, and NSW. Early training courses, of a few weeks duration, were offered in the techniques of programming appropriate to each machine. At that time, of course, to use a computer *at all* really required knowledge of programming. It was, however, some time before education in computing was seen anywhere other than university departments of statistics and mathematics. Programming courses were given regularly in the University of Melbourne from 1956, and in 1959 a formal subject in *Numerical Methods and Computing* was developed by Pearcey as part of the undergraduate BA course in pure mathematics. Undergraduate courses in the *Theory of Computation* commenced in 1964 with the establishment of the Department of Information Science (Pearcey 1988).

The study of statistics is a field which has always required knowledge of mathematical and computational processes, and up till the 1950s, university departments of statistics provided such knowledge. Departments of mathematics tended to ignore numerical mathematics and considered advanced numerical skills to be somewhat undignified. To some extent this attitude was to continue as a resistance by the

educational establishment to the new Computer Science, arguing "that it was not an academically well-founded discipline" (Pearcey 1988). It was not until the early 1960s that the universities accepted that Computer Science was a different discipline to mathematics.

Early Business Computing Courses

Before the entry of the digital computer, punched card accounting machines were used by many businesses, and early courses in their use were offered by the suppliers. By the 1930s the accounting machine had evolved into a quite sophisticated electronic calculator capable of performing complex arithmetic tasks and of processing dozens of punched cards per minute. Early courses in the use of accounting machines in Victoria's Technical Colleges introduced students to concepts including formal analysis of problems using techniques such as those of Organization and Methods (O&M) (Organization and Methods may be defined as the systematic and objective examination of an organization and its detailed methods of working in an endeavor to gain increased efficiency.) and Systems Analysis, as well as introduction to the concept of programming (Maynard 1982). They also prepared the ground for later Business Computing courses.

At a computer conference in Sydney in 1951, Trevor Pearcey was apparently asked "Do you think these things will be of any use in the commercial business area?" to which he replied with an emphatic "No!" (Philcox 1978). Pearcey believed that "you would not waste expensive computing resources on such mundane things as business computations" (Maynard 1990).

Entry of the Commonwealth Government

Once computer technology had been developed, the practice of computing was first put into serious use by the Commonwealth Government in the early 1960s with the requirements of the Commonwealth Public Service Board for large

numbers of computer professionals to staff its administrative computing projects in the Department of Defense and in the Postmaster-General's Department (PMG). A big problem though was that there were not enough of these qualified computing personnel. This was further aggravated by commercial projects beginning to be undertaken in large companies such as BHP, CRA, CSR, the banks, and the airlines. (Because of the cost of computers at the time, it was only large companies and the government itself which could even consider their use.) All these commercial projects required systems analysts, systems programmers, and application programmers who were in very short supply and commanded very high salaries. Feasibility studies took years to complete; long periods were taken up with planning, tendering for hardware and operating system software, selection of suppliers, installation, and formal acceptance. Supply delays of 1–2 years were normal. Getting computer professionals from overseas was not easily possible either as a number of other countries were in a similar position.

There was an urgent need for training, and the 4-week courses of a manufacturer, coupled with knowledge of the job in the firm, were not considered sufficient qualification. What was needed were courses with a substantial component that was vocational in nature, and the universities seemed uninterested in providing these being more interested in theoretical Computer Science.

The solution was that the Commonwealth Public Service Board (PSB) should provide leadership in course provision and that control of the training function should be centralized (Philcox 1978). The training needs of these projects were the main spur to the introduction of courses in Business Computing in tertiary institutions in Australia and in Victoria in particular.

The Programmers-in-Training Scheme

In 1960 the Board ran its first courses in *Analysis and Design of Mechanised Systems* and *Systems Analysis and Design* for its middle management

officers. These courses involved 12 weeks of full-time training, both theoretical and practical, and were conducted at the PSB's Automatic Data Processing (ADP) Training Centre in Melbourne. Course content included:

Introduction to systems analysis and design	1 week
Basic programming	5 weeks
Equipment characteristics	1 week
ADP systems analysis and design	5 weeks

Regarding its 12-week training as successful in providing "crash computing courses" in computing, the PSB recognized a need to set up longer courses and began designing a full year long *Programmer-in-Training* (PIT) course. The first PIT course ran in 1965 and initially drew upon the defense staff's experiences with both computerized and existing noncomputerized administrative systems. The PIT courses took over 20 h per week of formal class time for a year and operated initially in Canberra and Melbourne but later also in other capital cities. An outline of the 46-week course was:

Phase 1 (10 weeks)	
Introduction to the Course and to the Service	1 week
Computer equipment and techniques – Stage 1	1 week
Computer mathematics – Stage 1	1 week
Programming – Stage 1	5 weeks
Systems analysis and design – Stage 1	1 week
Examinations	1 week
Phase 2 (12 weeks)	
Departmental training – Stage 1	
Phase 3 (12 weeks)	
Computer equipment and techniques – Stage 2	1 week
Programming – Stage 2	4 weeks
Systems analysis and design – Stage 2	4 weeks
Mathematics – Stage 2 (statistics)	2 weeks
Examinations	1 week
Phase 4 (12 weeks)	
Departmental training – Stage 2	

The programming part of the early PIT courses started off with a study of machine code and then moved to assembly language before finally getting down to Business FORTRAN which was a

very powerful language developed by Control Data. Later, studies of COBOL and PL1 were also introduced (Maynard 1990). A problem was that programming and operating systems differed between different makes of computer system, and equipment suppliers each had an entirely different approach to computing that also needed to be considered when designing Systems Analysis courses. Although there was no formal syllabus for Phases 2 and 4, the Commonwealth Departments who took on trainees were required to prepare, in advance, a program for each trainee. This program had then to be submitted for approval by the Public Service Board (Grainger 1967).

PIT courses continued under the Commonwealth PSB until late in the 1960s when responsibility transferred completely to the tertiary education sector: to several of the newly formed Colleges of Advanced Education (CAEs). These PIT courses set the style for many of the courses later offered in the CAEs and Institutes of Technology. Although a number of Australia's universities had access to computers during the 1950s and some had even begun to take the teaching of Computer Science seriously, during the early to mid-1960s, they were both unready and unwilling to take up the challenge of turning out what they regarded as people with "vocational training" in computing. It was the Colleges of Advanced Education and Institutes of Technology which began to develop these courses. From that point on, a discipline of *Computing*, which was wider than Computer Science and was soon to encompass what we now call Information Systems, began to develop.

Courses in Colleges of Advanced Education in the 1970s and 1980s

One of the first educational institutions in Australia to adopt computing as a priority teaching area was the (then) Caulfield Technical College (Later Caulfield Institute of Technology and then Chisholm Institute of Technology) in Melbourne. As early as 1961, Caulfield had

offered a *Certificate of Accounting (DP)* course and by 1964 a number of short, evening, post-diploma courses in various aspects of computing: *Punched Card Systems*, *Accounting Machine Applications*, *Commercial Electronic Data Processing*, and *Principles of Analogue Computing*. Maynard (1990) reflects that in both Australian and worldwide terms, these courses were very early: "people were still teaching accounting machines – IBM punch-card machines. They were trying to move from punch-cards into the computing arena, but IBM was very slow in really getting computers into business." Braverman (1974) explains that learning to use punched card machines involved the equivalent of an apprenticeship where a period of learning was done on each type machine and the programming (wiring a panel board for each machine) done at this time was "simply the highest skill of an all-around trade." Juliff (1990) reports that in tertiary institutions, the equipment-based subjects of the 1960s typically spent roughly equal amounts of the time discussing accounting machines, punched card machines, and computers.

At Caulfield in 1964, the new *Diploma of Information Processing* was aimed at educating students "... in the operations and capabilities of data processing equipment as well as an appreciation of the principles involved in technical and commercial applications of this equipment" (Greig and Levin 1989). In 1967 the *Diploma of Business Studies (Data Processing)* commenced as a forerunner of many later courses in Business Computing.

In 1970 the Commonwealth Public Service Board handed over the running of the Programmer-In-Training course to four selected institutions, Caulfield Institute of Technology, Bendigo Institute of Technology, Canberra College of Advanced Education, and New South Wales Institute of Technology, as it "... believed that the increasing use of sophisticated computer equipment at the colleges and their need for increasing numbers of trained 'computer personnel' made such a development desirable" (Greig and Levin 1989). In 1971, the first year of operation of the "new" PIT program, the scheme

supported 235 trainees Australia-wide (Philcox 1978). This new scheme had the wider objective of providing trained computer personnel to industry as well as to the Commonwealth and State Public Service. Although similar in content to the early PIT courses, those delivered by Caulfield Institute show some maturation:

Phase 1: Ten weeks, 9 am–5 pm, Monday–Friday, at Caulfield Institute	
Computer Mathematics, Problem Logic	2 weeks
Data representation, computer equipment	1 week
Principles of programming	3 weeks
Applications programming	4 weeks
Phase 2: Twelve weeks of on-the-job training in present organization	
Phase 3: Ten weeks, 9 am–5 pm, Monday–Friday, at Caulfield	
Statistics and quantitative analysis	2 weeks
Systems programming	3 weeks
Data communications	1 week
Systems analysis and design	4 weeks
Phase 4: Twelve weeks of on-the-job training in present organizations	

In the early 1970s, Caulfield introduced the first commercial computing degree in Australia, the *Bachelor of Applied Science (EDP)*, that was later renamed *Bachelor of Applied Science (Computing)* with the primary goal of “developing computer professionals for employment in government and industry” (Greig and Levin 1989). During the mid-1970s a joint course combining the core elements of the *Bachelor of Applied Science (Computing)* and the *Bachelor of Business (Accounting)* was instigated as this was conceived as being of value to both students and prospective employers, as students completing it gained accreditation from both the Australian Computer Society (ACS) and the Australian Society of Accountants (ASA). From this time many other CAEs around Australia began developing similar courses in Business Computing. Also in the 1970s, many courses began to move students off the use of punched cards and onto terminals, but this was a slow operation taking 10 years to complete. Minicomputers could still be run on cards, and it took quite

a while for some institutions to be weaned off them. “Cards were much more concrete: you could take a pack of cards with you” (Juliff 1990).

University Computing Courses from the 1970s

Typically university Computer Science courses were initially sponsored by Mathematics Departments, and there was resistance to this new subject from many of the other mathematicians (both pure and applied) who saw Computer Science as just another kind of mathematics. Most universities saw computing in terms of mathematical Computer Science with little or belated attempt to relate to business or industrial applications. At the University of Melbourne, for example, under considerable outside pressure at the time the Department of Computer Science introduced COBOL and Systems Analysis courses to make its students “employable,” Melbourne seemed to be little interested in teaching about the commercial uses of computing and so contributed little to this area (Wilde 1992).

In other universities some attempt was made to make Computer Science more practical. At La Trobe University, Woodhouse (1992) describes how in the 1970s it was a “constant battle to get the purists to accept Computer Science as a significant study in its own right.” A Department of Computer Science was set up at La Trobe in 1978. In 1977 at La Trobe University, the *Graduate Diploma in Computer Science* took its first intake of students. Not wanting to create a course in *academic* Computer Science of the type offered by Melbourne and many other universities which would be “of little use in producing employable computer professionals” (Woodhouse 1992), in addition to programming (ALGOL, Pascal, 6800 assembler, PDP-11 assembler, and COBOL), software engineering, computer organization, and operating systems and Information Systems, La Trobe added Systems Analysis and Design (not then really considered to be a proper part of “real”

Computer Science) along with Introduction to Accounting, Management Accounting, Numerical Methods, Operations Research, and Social Psychology.

Types of Computing Courses

The question of whether *Computer Science* was a branch of science or a branch of engineering or whether it was something else entirely unique had been under discussion since the 1950s, and consensus only emerged by the early 1980s that it was a distinct discipline (Gries et al. 1989). *Business Computing*, which some had suggested was “just a watered down version of Computer Science located in an organizational context,” took a little longer to gain disciplinary status. *Business Computing* (or *Information Systems* as it is now called) was seen as “curricula designed primarily to educate people in the efficient and effective application of computer hardware, software, and systems to the solution of business and organizational problems.”

It is useful to consider the relationship between three separate computing course entities during the 1970s that have grown up together to produce the current courses in *Computer Science* and *Information Systems*:

- Academic Computer Science courses taught at most universities
- The Applied Sciences type of Business Computing taught in the CAEs
- Faculty of Business degrees in Business Computing taught in the CAEs

Business Computing to Information Systems

In the 1980s it was typical in the CAEs for somewhat different forms of computing to be taught in Faculties of Business and Applied Science. For instance, at the Bendigo College of Advanced Education (1984):

- *Bachelor of Business (Data Processing)*. This typically consisted of general business subjects including Accounting, Economics, Business Statistics and Business Law, several Business Data Processing subjects, and some electives.
- *Bachelor of Applied Science (Computing)*. This had rather more in common with a typical Computer Science course: Computer Programming, Information Systems, Finite Mathematics, Elementary Calculus, Information Processing Projects, Quantitative Management Techniques, Computing Machines, and several electives.

In the early 1980s, Footscray Institute of Technology updated its *Associate Diploma in Secretarial Practice* to include a substantial computing component: word processing, office automation, use of computer technology, and electronic mail. This brought Business Computing further into the Business Faculty. In 1987 at RMIT, a Department of Business Information Systems was set up. After this time at most CAEs, reference to *Business Computing* changed to *Information Systems*.

In July 1988 a Commonwealth “White Paper” (Dawkins 1988) set out a policy to recommend the abolition of the binary divide between Universities and Colleges of Advanced Education and the merger of the former CAEs either with each other or with existing universities to form new universities.

Around this time, traditional *Business Computing* curricular was beginning to develop into *Information Systems*, and most courses had a core of similar topics which were typically based around subjects related to Systems Analysis and Design, database design, business programming (which at that stage was typically done using third generation such as BASIC, COBOL, or Pascal), and Systems Implementation. Many of these courses at the time also had an introductory computer networking unit which was probably the most technical and close to the discipline of Computer Science. Subjects handling computer architecture were probably well into the realm of Computer Science and were often electives (Tatnall and Burgess 2009).

By the late 1990s and early 2000s, a typical course in *Bachelor of Business (Information Systems)* would contain some combination of the following subjects:

- Core business studies: Accountancy, Business Law, Economics, Marketing, and Management
- Computing studies: Systems Analysis and Design, Database Systems, Programming Languages, Database Management Systems, Networking Technologies, Information Ethics, Business Process Modelling, Information Management, IT Project Management, Systems Implementation, and Application Development

Conclusion

The mission of a university Department of Information Systems is quite clear: it must research, investigate, and teach how businesses, and other organizations, can make the best use of computers and information technology (IT) to further their business and organizational aims (Tatnall 2006). By its very nature, Information Systems (IS) is an applied discipline that is closely related to the use of information technology in business applications. Information Systems, as a discipline in its own right, is seen to be separate from Computer Science in that it concentrates upon the socio-technical aspects surrounding the implementation and use of ICT in organizations rather than the technical side of systems development. This does not mean that the more technical aspects of Computer Science do not have a place in Information Systems as the disciplines do overlap and those boundaries are often blurred. Courses in *Business Computing* in the CAEs did thus not diverge from university *Computer Science*.

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Blackberry Playbook

- [Tablet Use in Higher Education](#)

Blended Learning

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Synonyms

[Hybrid learning](#)

Definition

Over the last two decades, the term *blended learning* has been used more and more frequently in education, military, industry, and corporate sectors, as well as other organizations with training responsibilities (Moskal et al. 2013), and its definition has evolved over time. In fact, in the late 1990s and the beginning of the 2000s, *blended learning* was defined as any combination of technologies, pedagogies, and job tasks. For example, Driscoll (2003) viewed *blended learning* as different possible mixes of (1) web-based technology, (2) pedagogical approaches with or without instructional technology, (3) any form of instructional technology with face-to-face learning, and (4) instructional technology with actual job tasks. Other possible combinations were also added to the concept such as face-to-face learning with online learning, online learning with access to a coach or a teacher, simulations with structured courses, etc. Thus, *blended learning* meant different things to different people. Since 2006, the definition of *blended learning* has converged and stabilized. According to Garrison and Vaughan (2008), blended learning combines face-to-face learning with online learning in a planned, pedagogically valuable manner, to form an integrated instructional approach. As such, it is not a simple addition of online sessions to face-to-face sessions, but it supposes reassessment and reengineering of the entire course, including the use of new instructional strategies. In *blended learning*, teacher and students work together in mixed delivery modes in order to accomplish learning outcomes that are pedagogically supported through teaching, learning, and assessment activities, as appropriate for a given mode, and to offer a meaningful course environment to the students (McGee and Reis 2012). They have to rely strongly on a digital environment specifically structured and organized to support these mixed delivery modes.

Even if the definition of *blended learning* seems to be simple, it can take on different forms along a continuum, with a focus on face-to-face activities complemented with online activities on one end and, on the other end, a focus on online activities complemented by face-to-face activities.

For example, in primary and secondary education, a taxonomy of four models was developed by Staker and Horn (2012) using this notion of continuum: rotation, flex, self-blend model, and enriched virtual model. In higher education, other models exist such as supplemental, replacement, emporium, and buffet (Graham 2013).

Introduction

Improvements in information and communication technology (ICT) have had a significant impact on teaching and learning in education. New opportunities have arisen that were inexistent not more than a decade ago and have resulted in, among other things, a variety of course delivery modes such as web-facilitated face-to-face, blended, and online courses. A course delivery mode refers to decisions about the manner of presenting the content and teaching, learning, and assessment activities designed into the course. These new course delivery modes make it possible to recruit more students and to better accommodate them (Allen et al. 2016). Indeed, for example, online and blended courses meet the demands of students who desire flexible course schedules, like adult students who would not be able to attend face-to-face courses because of family and/or work responsibilities. Also, these various delivery modes give students better access to education especially in large and vast countries such as Canada, Russia, or Australia, where distances can be quite significant between students' homes and educational institutions. Finally, they can significantly decrease educational costs for students and for educational institutions. Students would not need to travel as much to attend face-to-face sessions while benefiting from direct or indirect contact with the teacher and other students. In addition, educational institutions can free up space on campuses as students and teachers no longer have to meet in person within a physical location for each class session.

Allen et al. (2016) placed the course delivery modes mentioned above on a continuum. At one end of the continuum is face-to-face mode, which involves traditional or web-facilitated teaching and learning. Face-to-face mode is called

traditional if there is no use of online ICT within the course. All teaching and learning activities are carried out in writing or orally. Face-to-face mode could also be web-facilitated; in other words, web-based ICT is used to facilitate and support the face-to-face course. In this mode, for example, the teacher could use a learning management system (LMS) or web pages to make the course outline and assignments available to students. At this end of the continuum, the proportion of teaching and learning activities delivered online can vary from 1% to 29%. Many examples of this mode can be found in primary and secondary schools, colleges, and universities. It could either be found in regular classroom contexts where students have multimedia resources to manipulate or at home in order to complete some asynchronous learning activities. These resources include videos, forums, social medias, quizzes, etc. For example, one chemistry teacher implemented a flipped classroom, which is a proper illustration of this specific context (<https://mrprofdechimie.com/classeinverse/>). It could also be used in a special context like regular classrooms with sports or arts concentrations in which some students have to travel every now and then for events related to their specialties and need to complete learning activities outside the classroom while traveling. For example, the Beauce-Etchemin school board offers this kind of online support for their students (<http://coursenligne.csbe.qc.ca/>). It could also be used in schools in small isolated locations that connect with other schools in order to open the doors of their classrooms to other realities. The *École en réseau* network in the province of Québec is emblematic of this context (<https://eer.qc.ca/reseau>). In these three cases, most of the learning activities take place in a synchronous manner, and all the learners are present in the classroom.

At the other end of the continuum is a mode in which most or all of teaching and learning activities are delivered online (80% and more). The Master's degree in secondary education of the Faculty of Education at the University of Sherbrooke is a specific example of this mode. For every course, the students have to carry out online activities either synchronously or

asynchronously on Moodle, Mahara, WebEx, or other platforms, except in one specific course that requires students to meet professors and peers in class for the presentation of their professional portfolio (<https://www.usherbrooke.ca/admission/programme/665/maitrise-en-enseignement-au-secondaire/>).

Finally, in the middle of the continuum is *blended learning*, which combines face-to-face and online modes. According to Allen et al. (2016), blended mode features learning environments in which 30–79% of teaching and learning activities are carried out through web-based ICT. These proportions might change from one institution to another, from one education level to another, from one context to another, and from one author to another.

It is worth noting that some authors emphasize the necessity of reducing face-to-face time of instruction in favor of online activities (Graham 2013), whereas others mention the strength of variation (Staker and Horn 2012). More and more universities adopt this course delivery mode, and many examples can be found online. For example, the University of Ottawa (Canada) offers a large number of courses within this format (<https://tlss.uottawa.ca/site/blended-initiative>). This university clearly defines a blended learning course as “designed such that some in-class time is substituted by equally meaningful online activities” and where many divisions are possible between face-to-face and online hours.

In light of the definition presented previously, “Blended learning should be viewed as a pedagogical approach that combines the effectiveness and socialization opportunities of the classroom with the technologically enhanced active learning possibilities of the online environment, rather than a ratio of delivery modalities. In other words, blended learning should be approached not merely as a temporal construct, but rather as a fundamental redesign of the instructional model with the following characteristics:

- A shift from lecture- to student-centered instruction in which students become active and interactive learners (this shift should

apply to the entire course, including face-to-face contact sessions)

- Increases in interaction between student-instructor, student-student, student-content, and student-outside resources
- Integrated formative and summative assessment mechanisms for students and instructor (Dziuban et al. 2004, p. 3)

Conditions for Success

In order to ensure successful learning within a blended learning course, different conditions for success and recommendations should be considered. Some of these conditions and recommendations apply to the general environment and others more specifically to course design or the course session. The following recommendations were identified from within the literature:

1. Gradually integrate blended learning, especially in education institutions where face-to-face instruction dominated for several years, and be aware of the stages of institutional adoption of blended learning (awareness/exploration, adoption/early implementation, or mature implementation/growth) because consideration of these stages could influence different levels of institutional support.
2. Ensure the availability of sufficient support from the education institution regarding the implementation of this course delivery mode. The implementation of successful blended learning courses requires alignment of institutional, teacher, and student goals.
3. Make sound decisions on the technologies and activities to be selected for use within the blended course. These decisions are taken according to teaching preferences and the technologies available in the education institution, and consider characteristics of the students enrolled in the course, i.e., age, maturity, learning styles and preferences, access to the Internet, ease of use of technologies, socio-economical background, etc.
4. Use the appropriate equipment in order to optimize students' experience within the online component of the course and to ensure students' access to learning activities and course material anytime and anywhere.
5. Test and practice the use of the various technological tools involved in the blended learning course before the beginning of the course. It is important for teachers to prepare in advance and to have some ease and facility using these tools. It seems to be even more important for teachers to reach a certain level of technological pedagogical knowledge to ensure good implementation and usage of these tools. It is also recommended to invite students to participate in training sessions for the technological tools being considered for use.
6. Test the functionalities of the communication system, the quality of the network connection, or the platform used in the blended course before the beginning of the course. These technologies should be performant in terms of functionality, robustness, and reliability.
7. Integrate different teaching and learning strategies in order to meet different learning styles. Moreover, blended learning is not the addition of online teaching and learning methods to face-to-face ones but requires new methods of teaching, learning, and content development and can rely on different forms of educational relationships and pedagogical control. In this regard, the redesign of a course would require 3–6 months based on a structured instructional design method. To be able to enjoy the benefits of blended learning, other possible blends should also be considered in the design.
8. Use asynchronous communication tools in the online component of the course to keep students engaged in the course, such as discussion forums or other social media.
9. Rethink the way that teacher and student roles are conceived. In blended learning, teaching and learning strategies should be more student centered. Teachers should enhance students' participation in their learning and support interactions in face-to-face and online sessions. If a class is considered as a community of inquiry, blended learning can create and sustain productive conditions that will benefit everyone engaged in positive learning experiences.

Advantages

Blended learning has been reported to be preferred by students to online courses and face-to-face courses. For example, the results of a study by Owston et al. (2013) conducted among university students revealed that blended course delivery mode was preferred to traditional face-to-face mode and online mode by high achiever students ($n=577$). Moreover, this mode is perceived as a “best of both worlds” approach as compared to online courses, and it may have a higher acceptance level and a higher perceived value (closer to face-to-face learning) than online courses (Allen et al. 2016).

It provides students with greater educational access, especially for those who live far away from campuses and for those who have a very demanding schedule for work or family responsibilities that make it difficult for them to attend face-to-face sessions every week.

It reduces educational expenses, and it may represent a solution for educational institutions with limited classroom space. It has been reported to increase student enrollment and to reduce instruction costs as the classroom resources are used more efficiently with a reduction of seat time.

It enriches the teaching and learning environment, as artifacts from face-to-face learning activities (such as audio/video recordings) may be used as learning objects, and artifacts from online learning activities (such as forums) may be used as learning objects in face-to-face activities. As such, blended learning offers teachers and students the “best” educational experience as compared to the traditional face-to-face or online learning.

It has been reported to be more effective and educationally beneficial for students as compared to face-to-face and online learning. Moreover, results of recent meta-analyses reveal that knowledge acquisition and achievement outcomes were higher in blended learning environments than those in face-to-face and online learning environments (Liu et al. 2016). Blended learning allows teachers to track students’ involvement and progress much better than in a

face-to-face learning environment. It also permits students to review digital materials as often as needed and at their own pace, which likely enhances learning performance. Moreover, as compared to online learning, students are less likely to experience feelings of isolation, which could in turn assist in maintaining interest in the subject matter (Liu et al. 2016).

Challenges

Lack of institutional recognition for the amount of effort needed to be put into the design of a blended course. This lack of support may leave teachers feeling unsupported in their efforts to innovate. Indeed, the blended learning course design demands much more preparation than courses in a single mode, i.e., face-to-face or online, such as setting up the rooms (both physical and virtual classes) and planning meaningful interactions and collaboration between students. These interactions and collaborations do not occur spontaneously and have to be well planned.

Students’ level of technological skills could be a challenge in this kind of course. If some students lack technological skills, teachers may focus on these students and spend their time troubleshooting students’ technical problems. The technologies used in these courses need to be easy to use, recent, and appropriate in order to motivate students to use them and to offer to them a meaningful learning experience.

Access to the online component of the course could represent an important challenge for students. The high cost of connectivity and technology issues may be important barriers for students in accessing the online component of the course and may compromise their learning. For example, cooperative tasks may be difficult to carry out in the virtual environment, and additional efforts may be required to foster group communicative interactions in the instructional process.

Lack of support and training for teachers. Even if blended learning can represent a significant reduction of costs, it still requires an important investment so that teacher’s competencies are developed to their fullest and benefit the

quality of teaching and learning. If the educational institutions do not support and do not offer sufficient training to their teachers, it might be difficult to create and sustain the productive conditions that could benefit everyone.

Other Terms and Approaches

The definition of blended learning, as explained earlier, has evolved throughout time, and some alternative terms are still present within the literature. Here are some of these terms. They can be easily linked to blended learning.

Hybrid learning is often used in the literature as a synonym of blended learning. However, according to McGee and Reis (2012), “hybrid suggests that one mode is unused, while the other is used” (p. 8). This means that the term hybrid refers to situations where there is a clear distinction between face-to-face activities and online activities, whereas blended suggests that there is no clear distinction between the face-to-face and online activities and no perceivable moments when modes shift.

HyFlex is a six-letter word that is a *portemanteau* of the terms *Hybrid* and *Flexible*. The Hybrid-Flexible (HyFlex) instructional model is a course design model that combines *Hybrid* learning in a *Flexible* way, such that students can either attend face-to-face class sessions, participate online, or do both according to their needs and availability.

Multiaccess learning refers to a “choice learning” mode where students control how they wish to participate in their course, with a distant small group via video conference or a face-to-face on campus group, individually by means of desktop web conferencing, or online asynchronously, etc.

Synchromodal learning refers to classes in which online students and face-to-face students interact with each other during shared synchronous sessions. As such, some students experience the course in a mediated format and others in an unmediated one. The delivery pattern in this course format includes lectures, linked classrooms, shared portals, personal portals, and small groups.

Blended synchronous learning is defined as mixing both asynchronous and synchronous online learning, to which face-to-face learning opportunities are added. It is about learning and teaching where distant students participate in face-to-face class sessions by means of video conferencing and web conferencing.

Blended online learning refers to fully online learning with synchronous and asynchronous teaching and learning activities.

Flipped classroom can be considered as a blended learning format that combines both face-to-face mode and asynchronous virtual mode. In a flipped classroom, asynchronous virtual activities are focused on the autonomous appropriation of mediated content or annotated preparatory readings, whereas face-to-face activities in the classroom are characterized by the valorization of active learning methods. Staker and Horn (2012) consider flipped classroom to be one of the rotation models in their blended learning taxonomy.

Conclusion

In conclusion, blended learning is an integrated pedagogical approach which combines face-to-face learning activities and online learning activities. It implies a reassessment and reengineering of every aspect of traditional courses and face-to-face class sessions. It requires teachers and trainers to redefine their instructional strategies and activities in order to support collaborative and active learning and to ensure that learning outcomes are reached in a meaningful context and adapted to the different modes of delivery.

This entry defined what is meant by *blended learning* and presented different conditions of success and recommendations to ensure successful learning within this course delivery mode. It also highlighted the five main advantages of using blended learning, but also explained that achieving a successful blended learning environment requires overcoming important challenges that every school, college, or university’s stakeholders, administrators, and teachers should seriously take into account: institutional

recognition for the amount of effort to be put into the design of a blended course, students and teachers' level of technological skills, access to the online component of the course, and quality support and training for teachers. Finally, other terms and related approach to blended learning were presented with the aim of providing a more complete portrait of the phenomenon.

Cross-References

- [Blending Learning Provision for Higher Education, Integrating “New Ways” of Teaching and Learning](#)
- [Classroom Use, Blended Learning](#)
- [eLearning in Saudi Arabian Universities, Toward Blended Learning](#)
- [Flexible and Distance Learning](#)

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Blending Learning Provision for Higher Education, Integrating “New Ways” of Teaching and Learning

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Synonyms

[Blended learning](#); [Changes in online learning](#); [Developing blended learning](#); [Developing professional practice](#); [Hybrid learning](#); [Learning with technologies](#); [Teaching practices with technologies](#)

Background

This entry explores how educational technologies are being used and can be used to develop what have been referred to as “new ways of teaching and learning.” These new ways, adopting a variety of forms of educational technologies, have variously been termed “e-learning,” “online learning,” and “blended learning.” In this entry, these “new ways” are examined, and key elements of technology, management, and pedagogy that must be focused on if future provision is to support both educational intentions and learner expectations are argued.

This entry will consider the question framed by its title – Blending Learning Provision for Higher Education: Integrating “New Ways” of Teaching and Learning. This concern, common to many institutions of higher education (HE) worldwide, will be examined through a policy and practice analysis perspective, taking existing literature in the field as a conceptual and contextual basis, considering examples of blended learning practices, identifying key features that support effective outcomes, and subsequently considering these in terms of implications for wider global practices where massification of education is being considered.

Focus and Purpose

This entry will critically review literature that has shaped and informed developments and practices related to “new ways of learning and teaching.” It will draw on the author’s experience and practices with online programs, and place these within a wider context, where increasing participation and massification are of fundamental concern.

Initially, definitions and uses of the terms e-learning, online learning, and blended learning will be considered, so that their use within this entry (and perhaps more widely) can be understood from the perspective of their delineation, since the different conceptions that underpin these terms have often been blurred or, indeed in some cases, the terms have been used synonymously.

E-learning is defined as, according to the outcomes of the study of Sangrà et al. (2012, p. n.p): “an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training, communication and interaction and that facilitates the adoption of new ways of understanding and developing learning.” These authors have elicited, using an appropriate methodological approach, what they consider to be an inclusive definition. It is clear that their inclusive e-learning definition, however, refers only to elements of programs or courses that use electronic media and tools. Consequently, e-learning is concerned fundamentally with forms of provision, rather than being led by concerns with teaching or learning.

Online learning, according to Watson et al. (2004, p. 95), is defined as: “education in which instruction and content are delivered primarily via the Internet.” Online learning is also, therefore, a term concerned with provision but focusing on provision where the Internet is primarily involved. Again, provision is fundamental here, rather than the concept being driven by specific approaches to teaching or learning.

Blended learning, according to Staker and Horn (2012, p. 3), is: “a formal education program in which a student learns at least in part through

online delivery of content and instruction with some element of student control over time, place, path, and/or pace and at least in part at a supervised brick-and-mortar location away from home.” Blended learning according to this definition is, therefore, not only concerned with provision but also with the ways that technologically supported and non-technologically supported elements of education might interplay or be integrated. It is this form of approach that, together with associated teaching and learning concerns, will be the focus of this entry.

Introduction: Parallel Research Concerns

Many HE institutions worldwide are investing in technologies to support teaching and learning, driven also by their need for engagement with wider and increased populations of students. In the latest Universities and Colleges Information Systems Association (UCISA) survey (2014), one of a series of such surveys and reports which have gathered evidence from HE institutions across the UK, all 94 institutions that responded in that survey reported using a virtual learning environment (VLE). This is recognized as a key technological tool (or rather a set of tools, which might include a bank of learning resources and a range of communication channels such as messaging, discussion forums and chat rooms, online assignment management, and online communities) to support blended learning provision, as it enables participation in learning activities that can happen at home or outside classrooms but further allows the integration of those activities and outcomes with those from within classrooms. In the UCISA (2014) survey, the most commonly, centrally supported technologies (which could well be linked to the VLE as integrated facilities) were plagiarism prevention and detection software and e-submission tools. E-portfolio, blog and e-assessment tools, and personal response systems (PRS) were also reported to be supported widely across HE institutions. Lecture capture and media streaming solutions were the emerging technologies that arose most often since the previous survey had been reported. It is clear that all

of these tools can be considered as those fundamental to support of different aspects of blended learning provision.

HE institutions are being driven to develop blended learning provision for one or more different reasons. Bonk et al. (2006, p. 560) identified from their survey a number of significant drivers, as well as a number of trends arising at that time, as HE lecturers considered developing and adopting blended learning practices: “[the rise in access to and uses of] mobile blended learning; [enhancements through] greater visualization, individualization, and hands-on learning; [greater control through] self-determined blended learning; increased connectedness, community, and collaboration; increased authenticity and on-demand learning; linking work and learning; changed calendaring [becomes increasingly easy]; blended learning course designations [are increasingly made available as options]; changed instructor roles [become more recognised]; the emergence of blended learning specialists [increases over time].” Ten years later, it is clear that these drivers and trends are still identifiable – and the external policy and social concerns are, if anything, more pressing and prevalent.

Such pressing policy and social needs have just as much a presence in India as they have in many other countries. With a plan to increase overall gross enrolment ratio (GER) in HE in India to 50% by 2030, this is calculated to lead to an estimated additional capacity need (let alone parallel, additional lecturer support need) for 40 million students in the sector (EY 2014). In this context, it is clear that the Government of India wishes to consider how to effectively develop online and blended courses and programs to increase and support the consequent, necessary HE access. As stated in a press release from the Ministry of Human Resource Development (2015): “Under National Mission on Education through Information and Communication Technology (NMEICT) scheme, 403 universities have been provided One Gbps connectivity and 21,766 colleges, including affiliated colleges through 20 nodes each of 512 Kbps broadband connectivity, so far. The Government does not

conduct online courses itself, however, it facilitates the educational institutes to make and offer online courses in various disciplines under NMEICT scheme.” While this press release states the development in terms of online courses, evidence about different forms of blended learning provision, with online learning lying at the more “online only” end of a spectrum, suggests that different forms, involving different blends of online and on-site provision, are worthy of consideration; different blends may match and suit different subject needs, as well as local and individual learner circumstances (see, e.g., Staker and Horn 2012, for a discussion of different options within the compulsory school sector).

Research has explored a range of perspectives within the field of blended learning. However, blended learning provision has certainly not been the sole concern of research looking at the entirety of educational development over the past few decades (the time since the Internet brought forward opportunities for high-speed and opportunistic communication between locations and individuals). Indeed, over the past 20 or more years, there have been a number of parallel streams of research in education and its future development. One of these streams has focused on approaches using technology-enhanced learning, while another has focused much more on learning and learning theories per se. At the same time, there has been a convergence, arising from concerns that research into technology-enhanced learning environments and situations should be considered in the context of emerging associated learning theories. Hence, there has been an emergence of research focused on fields such as “computer-supported collaborative learning” (see Stahl et al. 2006) and “networked learning” (see Dirckinck-Holmfeld et al. 2009), for example. In these cases, there is clearly a relationship argued between the provisions of education through uses of technologies (albeit perhaps in specific forms) and learning arising. The relationship between practice and research, and the limitations that a greater focus of research on technology might have produced, has recently been raised critically in these fields (e.g., Oliver

2011; Selwyn 2010). However, it is clear that practice using blended learning provision or approaches has been developed over the past few decades and indeed has been recognized to have been successful when measured through appropriate learning outcomes (see, e.g., Passey 2014). However, when outcomes have been identified as being successful, the roles of teachers have been recognized as being vitally important (see, e.g., Tamim et al. 2011). In this entry, it is argued that the roles of program and course aims and intentions are just as vital, and indeed those aims and intentions may themselves form the bases of interactions between the practice and theories that can underpin these programs or courses and subsequently lead to outcomes of recognized success.

“New Ways” of Teaching and Learning

Some authors and institutions might argue (and some certainly state) that there are “new ways of learning” (see, e.g., NTU Education 2012). But it is also possible to argue against these forms of assertion, especially since “new ways of learning” (where learning is concerned with the internal processes that the individual adopts) are difficult to identify. For example, while computer-supported collaborative learning has been identified as a field worthy of specific research activity, collaboration, as a way of learning, is not a “new feature” or a “new way.” The medium through which it occurs (communication technologies) is new (relatively speaking), but does this mean that the learning *per se* is “new?” Do learners using a technological environment, where collaboration is the focus, not also share their ideas, amend and modify, produce outcomes that integrate their ideas together, and end with an outcome or product that addresses a problem where their individual contributions are difficult to identify? The “new” element here appears to be the medium and the context in which it is occurring, rather than the learning.

If ideas of “new” ways of learning are to be accepted, then it is also necessary to recognize

“old” ways too. A “very old” way of learning, the Socratic method (described by, e.g., Gose 2009), is in some respects what some others might regard as “new,” since it involves learning through social interaction and questioning, rather than learning through a solitary individual focus where the learner is the recipient, taking on board what the teacher delivers. Trying to define “new” and “old” ways of learning is, therefore, potentially problematic. When learning arising from using new technologies is reviewed against a wide framework of learning elements (Passey 2014), it is not shown that “new ways” emerge. On the other hand, Passig (2007) has identified melioration as an additional thinking skill that he argues should be added to Bloom’s taxonomy (1956). But such identification is not common and is contested.

If broader learning approaches are considered, rather than more specific learning elements, then there are a number of “new” ways that have been claimed over the past 60 or so years. Some of the “new” ways that have been proposed are problem-based learning (PBL), described by Barrows (1996); authentic learning (AL) described by Donovan et al. (1999); dialogic learning (DL) described by Alexander (2008); situated learning (SL) described by Lave and Wenger (1991); technology-enhanced learning (TEL) described by Kirkwood and Price (2014); networked learning (NL) described by Dirckinck-Holmfeld et al. (2009); computer-supported collaborative learning (CSCL) described by Stahl et al. (2006); and mobile learning (ML) described by Crompton (2013).

When this list is considered, there is little doubt that the possibilities technologies afford have certainly been enhanced, not only has such enhancement arisen in terms of when learning can happen (e.g., as access can happen at any time if resources are online, through ML), and where (e.g., as access requires technological rather than physical access, through NL), but also how (e.g., as interactions can occur with a potentially wider variety of participants, at a distance, synchronously or asynchronously, depending on circumstances, through CSCL).

Shifts in Teaching and Learning Processes

But there is a need for some clarity and detail when considering how technologies can be integrated into teaching and pedagogical practices. When teachers deploy technologies to support pedagogies, the forms of provision mean that teachers need to consider the practices they can use to gain from the technological affordances available. Mishra and Koehler (2006) identified three areas of knowledge that teachers need as starting points (technological, pedagogical, and content knowledge). But these authors also argued that integration of technologies into teaching and pedagogy requires the development of forms of knowledge that bring these elements together, so that an understanding of the ways each one relates to the other can be applied within curriculum situations. However, it can be argued that considering pedagogy through a single educator mode (the teacher) is unlikely to provide sufficient breadth of ideas of how to undertake the width of practices that are opened up. Pedagogical knowledge will be affected by the mode that an educator might take (e.g., whether that mode is a teacher, focusing more on delivery of content and subject, or a tutor, focusing more on working with learners, or a guide, focusing more on supporting learners if and when they require assistance). The differences that these modes make to practice are not always easily delineated in some of the models associated with social constructivist approaches, which can tend to rely more on a tutor or guide mode. Models developed and used in this field of research, such as Laurillard's Conversational Framework (Laurillard 2002) or Mazur's Flipped Classroom Model (Mazur 2015), therefore, need to be considered further in the context of teacher or pedagogic mode.

Models and frameworks such as those of Laurillard and Mazur reflect on outcomes of approaches used to address more general demands worldwide for increased levels of HE, as well as increased opportunities through diversity of opportunities, not just in terms of subject and content, but also in terms of pedagogical

approach. While the trends to shift pedagogies are to move toward more situated, discursive, and socially constructive approaches, the trends to shift HE access are to move to higher levels of access, with increased learner numbers being supported by pedagogies that are focused on high output. Hence, perhaps, the support gained for massive open online courses (MOOCs) in recent years, due to access they provide being wide and high (although retention and outcome in terms of learning is not always reported to be strongly identified or necessarily high). However, researchers have argued that such levels of retention and outcomes should be expected (Koller et al. 2013).

The trend that is seen here is concerned with pedagogical shifts (that are also linked to necessary future skills): a shift away from transmission pedagogy; a greater balance between transmission and participative pedagogies; more of a focus on learner-centered approaches; concepts of social constructivism being integrated to greater extents; learner responsibilities being shifted; forms of engagement and activity widening; more individual responses and discussion being introduced; greater emphasis on tutoring, guidance, and facilitation; and a greater range of tools being introduced and used.

Teaching for the future needs to consider how ongoing change, where technological tools are introduced, can harness and develop practices in supporting a balance between transmission and participative pedagogies, finding ways to enable students to develop and share ideas and their approaches to study (e.g., discussed by Murphy and Wolfenden 2013); a focus on student-centered approaches, perhaps considering what is being called the "flipped classroom" model, where video or audio is used prior to classroom sessions, which are followed up by in-class discussion and reflection (e.g., discussed by Mazur 2015); concepts of social constructivism being integrated to greater extents, allowing for students to discuss and question through various formats, in groups in class, via a VLE or even via social media; student responsibilities being shifted, and how learners will gain a greater autonomy for learning through wider self-regulation (and perhaps this latter

competence being “taught” or “tutored”); forms of engagement and activity widening, being able to see and experience a width of activities that others are undertaking, through video case studies, for example;; greater emphasis on tutoring, guidance, and facilitation, but without losing the necessity for direct teaching where appropriate; and a greater range of tools that are being introduced and used, and how to identify the affordances for pedagogy and content that these bring.

What Is New: The Management of Learning

What is clear is that the management of learning and the management of learning activities can be developed and shifted using new technologies. The management of learning and learning activities means that provision can be blended, teaching can be blended, but learning can remain focused on identified learning aims and objectives, essential skills, and outcomes. Provision (a proportion at least) might as well occur at a distance, and in different forms, which should involve a range of activities, perhaps discussion, review, or use of online simulations, for example, covering asynchronous online activities or synchronous video chat.

The management of blended learning is seen to offer benefits for learners and teachers. A report of findings in the State of Victoria in Australia (Department of Education and Early Childhood Development 2012, p. 22) stated a wide range of benefits that can also apply to students in HE: “inclusion of more differentiated/personalised instruction; increased access to resources, experts and learning opportunities; more authentic and student driven tasks being incorporated into the curriculum; higher student engagement; greater opportunities for collaboration (especially beyond the classroom and involving the wider school community); exposure to a wide range of Web 2.0 technologies and acquisition of contemporary literacy skills; better access to infrastructure and, anytime, anywhere learning.”

Online access allows a greater emphasis on mentoring and guidance, with learners taking

greater control and responsibility for their learning. Studies have shown that using technologies can support teachers shifting their focus away from lower-order thinking and skills toward higher-order thinking and skills (Toyoda 2015). For example, use of simulations can allow a greater focus on analysis. However, at the same time, there is a need for learners to have high levels of self-regulation with regard to their engagement and learning. Interestingly, studies have shown that, when learners who have been involved in school systems where regulation is highly focused on school regulation rather than self-regulation, dependency on school regulation can persist in learners (Raahem and Wankowski 1981). It seems that a focus on supporting self-regulation (a key characteristic of expert learners or megacognition, Passey 2014) should be a major concern for future educational systems, whether these systems adopt on-site, off-site, or blended provision models.

Modes and Globalization

Globalization, and the opportunity for all young people and learners to have access to education, places huge demands upon educational systems and practices. At this time, it is difficult to see that there are sufficient numbers of teachers available to support the number of students who currently wish to learn; yet this figure will continue to increase and not decrease in the future. Whether greater opportunities through using technologies to support blended provision, blended teaching, and focused learning can be achieved is not a new question. But what is clear is that current and future teachers need to be prepared for modes that go beyond on-site provision; the practices of tutoring, facilitating, and guiding require different qualities and concerns. The forms of teacher support provided by School of the Air in Australia, for example, or by the UK Open University undergraduate or graduate programs rely on limited or particular teaching support, with far greater emphasis placed on self-regulated learning, where the learner takes more responsibility for lower-order knowledge acquisition, understanding, and comprehension, while

online activities and interactions support the need for more higher-order skills such as application, analysis, synthesis, and evaluation. Teacher opportunity and location, as well as learner opportunity and location, also need to be considered in this context. CNED (the National Centre for Distance Education), an arm of the Ministry of National Education, Higher Education, and Research in France, is a large organization, comprising some 100 employees in the central management team and some 2,200 teachers (most of these undertaking marking of completed work rather than interacting online). The number of employees is some 3,500 in total (some 1,200 employees developing online resources). CNED makes available about 500 courses, with some 3,000 modules, for students across the age range, from primary to secondary, vocational, higher, and professional education (CNED 2014). The organization has supported the educational needs of those not able to attend educational institutions for whatever reason (physical, mental, or emotional). Teachers who are not able to physically attend schools are employed by CNED, enabling an additional pool of expertise to be accessible to learners.

In the context of India, such opportunities are worthy of some consideration. The UNESCO e-Atlas of Teachers (n.d.) estimates that India will need to recruit three million teachers by 2030 due to the demand arising for new posts and due to current and future attrition. The UNESCO Institute of Statistics (2016) states that there are currently 181,872 HE students from India studying abroad; most of these are in the USA (97,613), Australia (95,562), and the UK (19,604). Taken together, it is clear that the demand for education will increase, yet it is unlikely that the demand can be sustained economically in the same way that it happens currently. “New ways of teaching and learning” are therefore likely to be required to manage this emerging situation. Exploring current patterns of managing blending learning that are recognized as being effective is one way to develop possible models that might support the necessary massification of education.

Examples of Blending Learning Approaches in HE in Lancaster University

The Department of Educational Research at Lancaster University has developed blending learning approaches over many years. It offers four different online programs for doctoral study. There are few such programs worldwide at this level, and different ways of blending provision have been considered and adopted with these programs. There are modular assessed elements, followed by a longer in-depth study that leads to a thesis, which is assessed by an academic panel (usually an internal and an external examiner). The residential provision in these programs (to support social as well as intellectual interaction) is blended in different ways: in one program there are a number of regular weeklong residentials; in another program there are 1-week residentials in each of the first 2 years; and in the other two programs, the provision is entirely online (Educational Research Lancaster University 2016).

The example focused on specifically is the e-Research and technology-enhanced learning doctoral program. Although a number of tutors support this program, there is very little focus on teaching per se. Most of the focus is on tutoring, facilitation, and guidance. Learners work through activities, reading key literature, perhaps summarizing, discussing, or drawing out key points or comparisons with other literature. In a range of activities, they make their individual findings accessible to other learners within an annual cohort and to the tutor, who can pick up on any specific points, facilitate discussion by leading on pertinent or related points, and guide on key principles that are emerging. The learner is supported as a self-regulated learner, with a focus on authentic learning (encouraging students to reflect on and undertake studies within their own contexts which can inform their own practice) and problem-based learning (encouraging them to identify key issues and challenges that they face and to use research approaches to consider possible ways to examine these problems).

Blending Learning Provision for Higher Education, Integrating “New Ways” of Teaching and Learning, Table 1 Technology resource categories and examples of technologies supporting “new” ways of learning

Digital technology resource category	Supporting “new” ways of learning	Technology examples
Topic-specific resources and software	PBL, AL	Specific online texts and literature Specific online videos and activities Pointers to online resources in other repositories
Curriculum-wide learner-centered software	PBL	Moodle platform for drawing together all key interactions Discussion fora
Curriculum-wide tutor-centered software	PBL, AL	Access to tutor resources is available to all students Tutor-prepared video clips Online assignment upload Online feedback
Online learner support	PBL	Tutor online summaries Tutor-highlighted resources and individual as well as group feedback

To support the focus on these “new” forms of learning, technologies are used in specific ways (which are exemplified, but not exhaustively, in Table 1).

Using this environment, there is a clear need for learners to be self-regulated and to develop self-regulation (discussed by, e.g., Zimmerman 1986) and the need for them to have access to resources and to ways to handle their identity and agency in this context. So, while there is a strong argument for considering these “new” ways of learning, there are factors that need to be considered in parallel, if efforts are to be successful.

Roles of Teachers and Students

Teaching in classrooms is often blended, with different modes deployed at different times (e.g., a teacher mode is used when some specific topic content is covered, a tutor mode is used when working with a small group focused on a specific activity, a facilitator mode is used when monitoring project-based activities, or a guide mode is used when taking a group around an external site such as a museum or castle). Choosing pedagogical practices associated with these four educator modes is a key element of the teaching armory accessible to the educator. An educator might

Blending Learning Provision for Higher Education, Integrating “New Ways” of Teaching and Learning, Table 2 Types of interaction related to pedagogical modes of educators. (Source: Passey 2016)

Type of interaction	Teacher	Tutor	Facilitator	Guide
Instruction	√	√		√
Explanation/illustration	√	√	√	
Direction	√			√
Demonstration	√	√		
Discussion		√	√	√
Scaffolding	√	√	√	√
Questioning	√	√	√	√
Speculation		√	√	
Consolidation	√	√	√	
Summarizing		√		√
Initiating/guiding exploration		√	√	√
Evaluating learners’ responses	√	√	√	√

deploy these in different contexts; Table 2 provides an illustration of possible matches between these modes and different types of learner interaction that might be involved (these types of interaction being taken from Twining and McCormick 1999).

It is clear from Table 2 that if all types of learner interaction are deemed useful, and are to be accessible to learners, then educators need to adopt a range of different educator modes. How this can be done when using different (and online) technologies becomes a key question when blending learning provision.

Curriculum Design Implications

If the focus of blended provision is to support both effective self-regulation of learners and effective teaching, then the types of interaction and modes of interaction in Table 2 need to be considered in terms of the aims and intentions of programs as well as modules or activities. Where do the fundamental learning needs of a program, module, or activity lie, if online teaching and support is something that will be affected by blended provision but the overall strengths of interactions need to remain?

From Table 2, reducing the elements that are limited by the blended provision (the “teaching” column), and enhancing the elements that can be highlighted by the same provision, a suggested (perhaps ideal) pattern is exemplified in Table 3.

Using the elements in Table 3 as a design model, a program or module would then rely on involvement of the highlighted key factors. Experience in the program run at Lancaster University, and research outcomes from studies focusing on implementing blended learning in various sectors of education (e.g., Department of Education and Early Childhood Development 2012; van Merriënboer and Kirschner 2012) indicate that certain of these factors are relied upon heavily or focused as priorities (related to key aims and objectives of programs, modules, or activities). In terms of influential and important factors, these are:

- Evaluating learners’ responses through tutoring, facilitating, and guiding. Online interactions and responses allow educators to explore and analyze learner responses carefully, considering the strengths of each learner, the gaps or misconceptions in their understandings that might exist, and the ways that the

Blending Learning Provision for Higher Education, Integrating “New Ways” of Teaching and Learning, Table 3 Types of interaction related to pedagogical modes of online educators

Type of interaction	Teacher	Tutor	Facilitator	Guide
Instruction	√	√		√
Explanation/illustration	√	√	√	
Direction	√			√
Demonstration	√	√		
Discussion		√	√	√
Scaffolding	√	√	√	√
Questioning	√	√	√	√
Speculation		√	√	
Consolidation	√	√	√	
Summarizing		√		√
Initiating/guiding exploration		√	√	√
Evaluating learners’ responses	√	√	√	√

learner is approaching their learning. This allows educators to accommodate diversity in learning approaches, evaluating forms of interaction that might support individuals and groups most effectively.

- Discussion through tutoring, facilitating, and guiding. Educators might rely upon learners working in groups, initiating discussion, and expecting learners to participate. This allows learners to gain from the experience of others and to be involved in sharing their views and ideas, exposing and developing their understandings, and arguing their positions and findings.
- Scaffolding through tutoring, facilitating, and guiding. Educators can scaffold carefully the activities through each module of a program. Educators might identify key readings, ask learners to perhaps summarize these in groups, discuss key points, highlight weaknesses and strengths of aspects of those readings, and consider how they would apply these within their own contexts. Educators can support research and proposal writing and scaffold approaches to research studies.

- Questioning through tutoring, facilitating, and guiding. Educators can ask learners to focus on questioning, critiquing, and highlighting assumptions, rather than stating without substantiation. Educators can be concerned with criticality, supporting learning that arises through problem-solving based on questioning.
- Summarizing through tutoring and guiding. Educators can ask learners to highlight key points and to summarize and to present précises, for example. Educators can facilitate conceptualization, asking learners to consider, adopt, or develop theoretical frameworks and models and how they will relate these to their own studies.
- Initiating and guiding exploration through tutoring, facilitating, and guiding. Educators can initiate and guide exploration, rather than teaching them directly. Educators can expect to shadow learners, offering comment and support along the way, rather than teaching discrete elements and then expecting learners to apply these randomly.
- Speculation through tutoring and facilitating. Educators can expect learners to think about content and concepts and to speculate, rather than to make assumptions. Educators encourage learners to think about options and possibilities and to explore limitations and future potential, rather than accepting what exists without question.

In blending learning provision, there is a need to be mindful of implications, for quality, accreditation, and access. While some might hold concerns about these practices and the implications for quality, accreditation, and access, the reality nonetheless appears to lie with how blended provision is handled, rather than blended provision being unsuitable. Having said this, blended provision clearly needs to accommodate specific subject and topic needs. Within my own subject area, education, it is perfectly feasible for blended provision to support any topics that might be identified. Within engineering, however, there could be greater limitations, where access to specific equipment might be needed. The blend is likely, therefore, to need to vary across subjects and across topics.

Quality of provision needs to be maintained by the management of the provision, the management of the teaching, and the management of the learning. Accreditation is an important element within this concern for quality. Criteria need to be clear, and the same standards for accreditation need to apply when programs are blended or totally on-site. Self-regulation needs to be built into this; learners need to acquire understandings of the standards required and the criteria that will be applied. Authentic learning and problem-based learning relate to this also: that the standards and criteria apply to authentic situations and problems in the individual's context. Once these are in place, then access becomes a reality. Access does not mean access to provision; it means access to the standards and criteria to judge the study that is undertaken. The location and the circumstances become less important when this is the case.

Possibilities for Remote Areas and Widely Distributed Communities

Blended programs at Lancaster University and elsewhere have shown that it is possible to involve and support learners who are remote and who would otherwise not be able to participate. The Educational Research Lancaster University blended programs support part-time doctoral studies with students who are located worldwide (e.g., in the Philippines, in Germany, in Namibia, in Oman, in Canada) and for those who are working full-time, who could not possibly attend a doctoral program on-site in England. They are enabled to focus on their work through their studies (a focus on authentic learning) and to focus on addressing research questions from their fields of work (a focus on problem-based learning).

Conclusions

There is already a rich literature that relates to the development of blended learning. However, the use of the term blended learning hides key factors that need to be considered when developing practices that bring on-site and off-site interactions

into an orchestrated whole. In essence, blended learning is only one of those factors; blended provision, blended learning, and blended teaching are key elements, and perhaps “blending learning provision” is a better way to consider the underpinning concepts.

The analysis of literature and practice presented here suggests that those developing blending learning provision should consider a number of key elements (not necessarily always in the order presented here, as context and focus may affect this order):

- Consider at a program and module level which elements must be undertaken on site, what time needs to be devoted to these, and where in the overall time plan such on-site activities should be located.
- For other elements, identify the learning aims and objectives and how these relate to “new” ways of learning – problem-based learning (PBL), authentic learning (AL), dialogic learning (DL), situated learning (SL), technology-enhanced learning (TEL), networked learning (NL), computer-supported collaborative learning (CSCL), or mobile learning (ML), for example.
- Consider what forms of learning activities can be used to enable the aims and objectives to be met, using “new” approaches to learning, based on a selection of appropriate interactions – instruction, explanation/illustration, direction, demonstration, discussion, scaffolding, questioning, speculation, consolidation, summarizing, initiating/guiding exploration, or evaluating learners’ responses.
- Consider the educator mode or modes that will support these selected activities and learner interactions – teacher, tutor, facilitator, or guide.
- Select the technologies that will support or fulfil these educator-supported activities and interactions – topic-specific resources and software, curriculum-wide learner-centered software, curriculum-wide tutor-centered software, or online learner support.

Blending learning provision will continue to develop as new technologies emerge, practices are implemented, and research identifies the

outcomes of those practices. Interest from universities worldwide in exploring and developing online doctoral research is evidenced from presentations on this topic at conferences and seminars, for example, a presentation at the 9th International Congress on Innovation in Education, 22 to 23 October 2015, Veracruz, Mexico; a presentation at the NEUPA and the British Council “International Seminar on Teaching-Learning and New Technologies in Higher Education,” 25–26 February 2016, New Delhi, India; and a presentation at the 13th Annual Conference on Research and Innovation in Distance Education and eLearning, London, UK. Research has an important set of roles to play in the future, not least to disseminate outcomes to and to support those who will need to shape the current and future, whether they are policymakers, practitioners, or other researchers. How effectively this is done may ultimately shape the value of endeavors for future learners.

Cross-References

- ▶ [Affordances of Technological Connectivist Tools in Higher Education](#)
- ▶ [Classroom Use, Blended Learning](#)
- ▶ [Distance Learning](#)
- ▶ [Flexible and Distance Learning](#)
- ▶ [MOOCs, Teacher Professional Learning and Deep Learning Conversations](#)
- ▶ [Restructuring Teachers’ Knowledge for Teaching with Technologies with Online Professional Development](#)
- ▶ [Teacher Education and Professional Development for Technology Integrated Teaching](#)

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Block-Based Programming Languages

► Programming Misconceptions at the K-12 Level

Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India

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Synonyms

Children with autism; Cross-cultural collaborations; HCI4D; Underserved communities

Introduction

Emerging technologies, such as affordable smartphones with 4G access, broadband Internet, and interactive interfaces employing gestures or speech, are revolutionizing the ways we access information, learn new skills, and interact with the world around us. However, developing world

communities – who stand to benefit from such technologies – were, until recently, largely neglected. Interactive technologies can provide a means to overcome social and literacy barriers toward information access. For instance, children with developmental disabilities can use hand gestures to collaborate with a typically developed peer, while rural farmers can use an interactive voice system to gain seasonal agricultural information. When introduced in public spaces, such as schools or community health centers, technology not only provides individual learning solutions and access to information but also encourages and enhances social collaboration and group learning. This potentially brings an overall improvement in people's quality of life, especially to the most vulnerable of these communities, such as rural women and men and children with special needs. Understanding these important user groups and designing for their needs requires a multidisciplinary and multicultural approach toward technology, an approach taken by researchers and designer working with the purview of Information and Communication Technologies for Development (ICT4D) (Heeks 2008) and Human-Computer Interaction for Development (HCI4D).

This chapter details ongoing research that is a collaboration with multiple partners across Finland and India, from both the industry and academia. The research focuses on designing, developing, deploying, and evaluating novel interaction techniques for education (Kallioniemi et al. 2015a, b; Pihkala-Posti et al. 2013, 2014; Sharma et al. 2016a, b, 2018, 2019), healthcare (Sharma et al. 2014), and agriculture (Kallioniemi et al. 2012; Ruohonen et al. 2012, 2013a, b, c; Srivastava et al. 2012) for underserved communities in India. With multinational and multidisciplinary teams across the world, this combined expertise focuses on multimodal interaction with devices, environments, and people to address many future challenges. In education, interactive gesture-based learning applications for children with autism were developed. An embodied navigational game for cross-cultural collaborations for underprivileged

children, who have limited access to technology, was also explored. In healthcare, the use of an interactive gesture-based information system for rural Assamese women was studied. In agriculture, a voice-based mobile agricultural information system for farmers in Karnataka was designed and deployed. These applications are collaborative efforts with Finnish and Indian partners: in Finland with different research groups at the University of Tampere, CIRCOMI and TAUCHI, and with Plural for CityCompass and in India with IBM Research and well-established Indian universities – Indian Institute of Technology in Guwahati, Assam, and University of Agricultural Sciences in Dharwad, Karnataka. In education, collaboration with local non-governmental organizations (NGOs) that cater to children with special needs and children from urban slums was further established. All applications strive to create meaningful user experiences and increase social impact, in addition to increasing technology access and utilization. In this chapter, the key findings from the work carried out in India on education, healthcare, and agriculture are discussed.

A Novel Approach to the Work

The work in India follows a collaborative and ethnographic approach, where researchers spend considerable time in the actual environment and with the different stakeholders. This starts with a user-centered design in which one or two members of the research team interview different stakeholders, for example, teachers, therapists, parents, and students in schools, to understand the challenges toward information access and learning. Together, the problem statement and research hypothesis are defined, and potential design solutions with regard to the type of technology available (mobile phones, laptops, or computers) and most suitable mode of interaction (full-body gestures, speech, or traditional mouse-based interaction) are identified. Then, one or more working prototypes or applications are developed and iteratively improved throughout the development

process, based on frequent stakeholder testing and discussions. The application is then tested in the real use environment and by actual users, during the user study phase. The final phase includes an analysis of the results and artifacts and publication of findings to guide future work. Following a design-based, user-centered, and ethnographic approach reduces the barrier toward technology acceptance in an otherwise sometimes technophobic environment.

When conducting user studies, there can be cultural barriers to communication. This is especially visible when working with schoolchildren, as rigid social norms arise from a complex hierarchical social structure. For instance, teachers usually initiate and guide learning experiences and conversations, and researchers are considered as teachers. However, equal participation toward collaborative problem-solving is desired. The Bollywood method enables users to communicate freely, from expressing issues in using a specific product or website (Chavan 2005). The Bollywood method was adapted to online collaborative problem-solving. It reduced the challenges arising from computer and gaming inexperience and known cultural barriers to communication, which in turn facilitated meaningful learning experiences that easily extends to other learning goals, domains and environments, and cultures and regions in overcoming cultural barriers to communication.

The Bollywood Method: While conducting usability studies with Asian participants, Chavan (2005) found that users would not share negative feedback out of politeness and were also hesitant in admitting the problems they faced. To overcome these barriers to social communication, she devised the Bollywood method. In the Bollywood Method users are presented with a dramatized scenario, akin to Bollywood *masala* movies, that requires them to take on the role of a larger-than-life character with a specific goal. For example, for testing an airline ticket booking application, users were asked to imagine that their niece is unknowingly getting married to an underground hit man, who is actually already married. The users have to book tickets to

Bangalore with the incriminating evidence in their sole possession to stop the wedding!

Information Access in Education

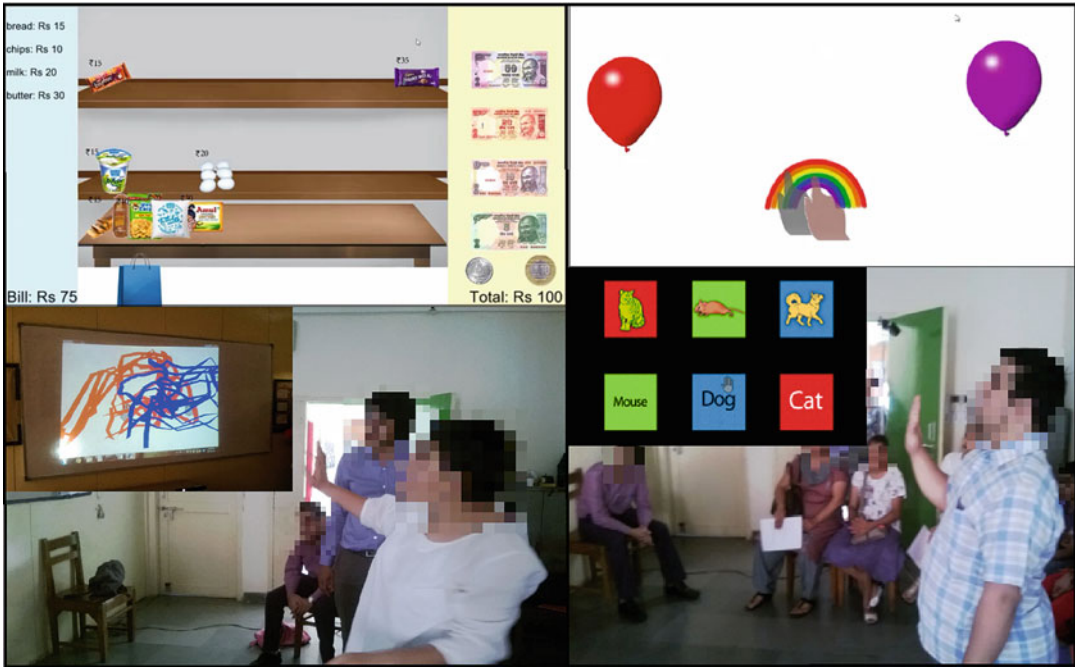
In education, the focus was on two groups of children: children with developmental disabilities and children from underprivileged regions. For children with developmental disabilities, multiple gesture-based applications were designed, developed, and evaluated. These applications employ the Microsoft Kinect sensor for motion tracking. This work was a collaboration with IBM Research Labs and the Tamana nongovernmental organization that caters to children with special needs in New Delhi (Sharma et al. 2016a, b). The term developmental disabilities is used to refer to a wide range of neurodevelopmental and/or physical disabilities including (but not limited to) autism spectrum disorders, Down syndrome, and other learning disabilities comorbid with ADHD, cerebral palsy, and other motor impairments (DSM-5[®], 2013). Autism is a neurodevelopmental disorder characterized by a lack of motivation for social interactions and difficulty in learning. Interactive technology offers several advantages for children with autism, including controllable input stimulus, multisensory learning environments, and opportunities to customize for individualized learning goals, structured, predictable, safe, and consistent learning environments (Bartoli et al. 2014; Mora-Guiard et al. 2016). Applications can also simulate real-world scenarios in a safe and controlled environment, and the learning is potentially translatable from the virtual to real world, facilitating self-efficacy. Therefore, it is no surprise that various institutions around the world have incorporated technological interventions for children with autism (Bartoli et al. 2014; Parés et al. 2004).

Employing gesture interaction for children with autism has gained favor in recent years with many researchers working toward developing innovative applications to motivate and encourage children to learn and interact socially (Mora-Guiard et al. 2016). However, much of

this research is focused on children from developed countries and is highly individual, as most of the applications are not collaborative in nature. In developing regions such as India, children with autism are still largely underserved. Moreover, there are several challenges toward adoption of novel technologies – from being expensive and catering to a limited group of people to being difficult to maintain and integrate into existing systems. Furthermore, individuals with developmental disabilities have limited access to these technologies, and therefore the digital divide – technical and economic barriers toward technology access – is more pronounced. In order to overcome these challenges, it is important to substantiate the potential of such technologies and build a stronger case for their adoption. This work is the first of its kind by employing gesture interaction for collaboration for children with autism in India. The applications include:

Kirana: The Kirana application was designed to teach the life skill of buying items from a local Indian grocery store by going through the subtasks of decision-making (deciding what to buy), arithmetic (calculating if they have enough money to buy), and social interaction. It was evaluated with children who were previously unable to shop by themselves. An educator provides the task – a list of items to purchase. The children are expected to purchase the items by pointing at the virtual items, pay for them by pointing at the virtual money, and check the itemized bill on the left side of the application screen to make sure the bill can be paid.

Balloons: Balloons promotes social interaction via joint attention, or the shared experiences over a common object, which is a crucial step toward social inclusion for individuals with autism. Joint attention has been linked to language acquisition and social interaction in the later stages of the neurological development of a child. The process of joint attention can be achieved in several ways, “including sharing attention (e.g., through the use of alternating eye gaze), following the attention of another (e.g., following eye gaze or a point), and directing the attention of another” (Dawson et al.



Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India, Fig. 1 Kirana store application (top left), Balloons

application (top right), and participants try the applications at the school's Diwali Mela (bottom row)

2004). In balloons, two participants have to select the same balloon together, within a 3-second timer, using verbal and nonverbal cues (Fig. 1).

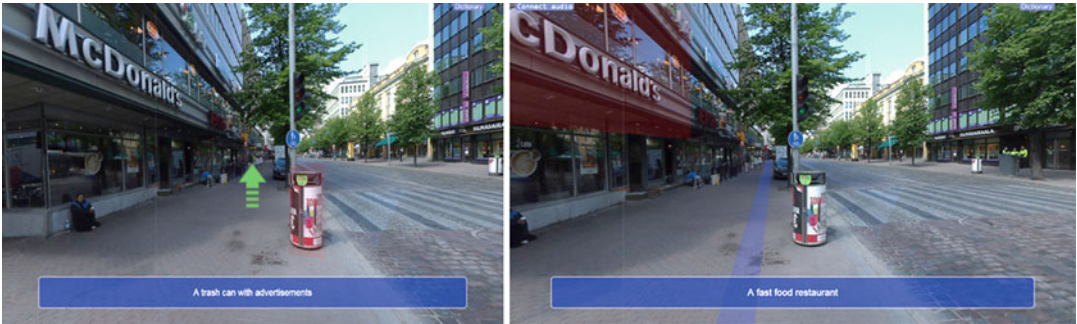
Our overall experiences with these applications suggest that involving different stakeholders, for instance, parents, therapists, and special educators, in the designing process reduces the barriers toward technology acceptance and adoption. Furthermore, applications that can be customized for different individuals, and also diverse learning goals, cater to a larger user group, making efficient use of resources. By taking into account the cultural implications of the environment, socially acceptable interactions can be designed. The work with Tamana is the first of its kind that employs interactive technology solutions for educational interventions for children with special needs in India. This work won the 2015 NASSCOM Social Impact award for Tamana.org (<http://engochallenge.org/winners-2015-using-digital-tools-to-help-people-with-disabilities>) (Figs. 2 and 3).

For the second group, children from under-privileged urban regions, studies with the CityCompass application to encourage children with computer inexperience to collaborate with a foreign researcher were conducted (Sharma et al. 2018, 2019). CityCompass is a virtual language learning application that uses 360 panoramic views of an actual city for collaborative tasks. It was designed by researchers in TAUCHI and Plural, at the University of Tampere. In the application, participants take on the role of either a tourist or a guide, and together they navigate through a series of panoramas to reach a pre-assigned destination. The educational and language learning potential of CityCompass was established in previous work with students in Europe (Pihkala-Posti et al. 2013, 2014; Kallioniemi et al. 2015a, b).

In India, CityCompass was used with children at Deepalaya, a nongovernmental organization focused on imparting education to marginalized children from slums in Delhi. The Bollywood



Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India,
Fig. 2 CityCompass.sis.uta.fi, the welcome page of the application



Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India,
Fig. 3 CityCompass tourist version (left) and guide version of the application (right)

method was added to CityCompass, and students were provided a dramatic story: of being lost on a school trip in a foreign city, with a sense of urgency, before interacting with the application. This created engaging and immersive learning experiences and improved cross-cultural communication. The results can be extended to online learning systems aimed at cross-cultural collaborations for language learning to other domains and cultures, allowing children from different cultures and backgrounds to experience the globalized world we live in (Fig. 4).

Information Access in Healthcare

In healthcare, the focus was on providing maternal healthcare information for users with low level of literacy, employing gesture-based input and audio-visual output using a Microsoft Kinect sensor, a laptop, and a TV display, eliminating the need to read or write text, as described next in the GILL project (Sharma et al. 2014). India has an acute shortage of trained physicians, and a lack of culturally sensitive health information, social inhibitions, prohibitive gender-based roles, poor



Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India,
Fig. 4 Deepalaya Learning Center Sanjay Colony (left) and a Deepalaya student using the application (right)

infrastructure, and an overall low health consciousness, especially within rural populations, are all deterrents for opting for professional healthcare. Providing health information initiates open dialogs among community members that lead to better health practices and helps overcome the prevailing social taboos associated with various health conditions. In collaboration with the Indian Institute of Technology – Guwahati, Assam, and IBM Research Labs Delhi – an interactive gesture-based health information system for rural Assamese women was designed, developed, and evaluated.

The application aimed at overcoming participants' inexperience with technology and functional illiteracy, by incorporating gesture-based interaction, which did not require users to read or write. Functional illiteracy means that even with some form of formal education being unable to say read a label on a medicine bottle to understand dosage. This can be a consequence of being unable to read or write (low literacy levels) or being unable to read the specific language on the bottle (high literacy but in a local language). Two gesture-based solutions were implemented in the application: *touching* or using the body-centric gestures to give input to the system, for example, touching one's head to input say a headache and *pointing*, where users pointed at a menu item on the screen. After investigating these interaction techniques, a clear preference for gesture-based

interaction employing local body-centric gestures was observed in the healthcare domain. Using the outcomes of Gill, interactive health information systems have been successfully piloted in clinics across Assam, and IIT-Guwahati won the Gandhian Young Technological Innovation Award for its work, Chetna+ project (Sorathia 2016) (Fig. 5).

Information Access in Agriculture

In agriculture, the prime focus was on the rural Indian farmers in the state of Karnataka. Working with local partners, a speech-based mobile application that provided relevant information was developed (Ruohonen et al. 2012, 2013a, b, c). Employing voice overcomes communication and interaction barriers due to functional illiteracy. Rural India relies heavily on spoken conversations as a primary mean of communication, because of literacy barriers. IBM Research Labs in India built the Spoken Web technology (comparable to World Wide Web) to provide users with voice sites (similar use as websites) that could overcome the literacy barriers to technology access (Kumar et al. 2010). Content on the voice sites could be recorded using a low-end mobile phone and in the local dialect, in order to provide information to rural populations (Kallioniemi et al. 2012; Srivastava et al. 2012). This provided



Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India, Fig. 5 The experimental setup at IIT-G (top left),

observation room (top right), interviewing participants post usage (bottom left), and a user interacting with the application (bottom right)

to be an effective way to overcome the current digital divide, especially regarding information access, and inspired several other projects.

The aim of this research was to develop viable mobile and multimodal services and business models for rural India to help the underprivileged – starting with agriculture. The application, *Krishi Jnana Vani* (Agricultural Knowledge Voice), provided agricultural information right from “seed to spoon” to local farmers to achieve sustainable agricultural practices. The information was in local Kannada language, which is spoken by 45 million people in Karnataka, and therefore the local farmers could interact in their own language. The voice site had information collected from already installed information kiosks at the University of Agricultural Sciences of Dharwad. These kiosks offered farmers agricultural information in textual format, so that content was recorded into audio format at *Krishi Community* local radio station in Dharwad. *Krishi Jnana Vani* offered information

first about three different crops, sorghum, wheat, and maize, and information about agri-processes such as crop improvement, production, post-harvesting, and pesticides. It was later developed to include information about 40 crops. In addition to technological solutions, successful service deployment requires contextual understanding about the users’ and their needs, the environment, and the local stakeholders. This understanding must be gained without overestimating or romanticizing the capabilities of the people. The major challenge for the bottom-of-the-pyramid people in rural India is access to services and relevant and reliable information. This means that a significant palette of localized voice-based services can be created to improve the situation, even when considering the natural limitations that these services have compared to human-operated services. For example, in agriculture the services can in the simplest form include dynamic information services considering production, processing, and marketing of the farm products and cash crops.



Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India, Fig. 6 Karnataka villagers interacting with services developed for RuralVoice

Our findings substantiate the potential of utilizing voice-based services and innovative business models for users in developing areas, such as in Asia, Africa, and Latin America (Fig. 6).

Conclusions

As technology become more affordable and pervasive in classrooms, community centers, and through mobile phones, interactive services provide a possibility to improve information accessibility in various areas and to overcome the functional illiteracy barriers associated with the low literate rural men and women. Further, these technologies can provide more innovative and more effective learning environments for children. From embodied interactive application for children with special needs, to language learning through cross-cultural collaboration, to interactive health information systems, and to mobile applications promoting sustainable agricultural practices, this research is actively involved in designing interactive technology and services that overcome literacy and accessibility barriers.

Future work in India focuses in the first phase (2018–2019) on education and healthcare in the context of building rural renaissance and

suburban development. Work in education consists of developing an immersive virtual reality CityCompass application that supports 360° video panoramas on an affordable smartphone placed inside virtual reality glasses, like the Samsung gear. For children with autism, the potential of wearable emerging technologies, such as the Fitbit activity trackers to encourage physical exercise, is being investigated. An internal consortium focused toward improving technology interventions and learning experiences for children with special needs is also being formed. In healthcare, information and learning access is being expanded to healthcare workers and their trainers. Collaboration with Global Health and Development group at UTA is underway with a focus on fostering mHealth applications for mother and infant well-being. The initiatives in India pave the way for designing applications for currently underserved Indian women and children, across schools and health centers in different villages and cities for reducing the digital divide.

Cross-References

- [Adoption of Virtual Laboratories in India, Learning Assessments and Roles of ICT Skill Learning Tools](#)

- ▶ Assisting Elderly Non-computer-Literate People with Computer-Based Communications
- ▶ Assisting People with Autism Spectrum Disorder Through Technology
- ▶ Assisting Students with Intellectual Disability Through Technology
- ▶ Assisting Students with Learning Disabilities Through Technology
- ▶ Assistive Technology and Inclusion, Philosophical Foundation
- ▶ Augmented Reality in Education, Scope of use and Potential
- ▶ Blended Learning
- ▶ Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India
- ▶ Educational Resources, Hypermedia
- ▶ Educational Support on Computing and Informatics for Disadvantaged Groups, An Empowerment Perspective
- ▶ Games, Simulations, Immersive Environments, and Emerging Technologies
- ▶ ICT-Based Inclusive Education
- ▶ Lifelong Learning for Working People
- ▶ Mobile Computing and Mobile Learning
- ▶ Mobile Learning
- ▶ Modeling the Process of Information Technology Innovation in Education
- ▶ Situative Perspective and Determinants of Technology Acceptance in Educational Technology
- ▶ Technology Enhanced Learning

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Bunyip, The Australian Educational Computer that Was Never Built

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Synonyms

Computer systems; Culture; Educational computing

Introduction

Software from organizations like the Minnesota Educational Computing Consortium was utilized in the late 1970s and 1980s in Australian schools, but, good though it was, it created a cultural issue as this software typically had an American outlook. Another example was the Apple][simulation game “Lemonade.” The game was based on making and selling lemonade from a street stall, but the problem was that lemonade stands are almost unknown in Australia. Of course the program had some merit in terms of teaching

students about mathematics and one aspect of doing business, but perhaps there was a better way of doing this. Many Australian schools used the Acorn BBC computer, but it had similar cultural problems, an example being “Suburban Fox.” This was a good game that involved students in acting as a fox to find food and avoid getting killed by a car or in a fox hunt. The fox had to watch out for bright lights when crossing a road at night and be wary of the sound of hounds baying. Again the problem is that this was quite foreign to Australian students.

In 1983 the Commonwealth Schools Commission set up the *National Advisory Committee for Computers in Schools* (NACCS) to provide advice on the implementation of its \$18 million National Computers in Schools Program that was aiming to offer a broad approach computer education in Australian schools (Commonwealth Schools Commission 1983). An immediate problem faced by NACCS was the widespread availability of a large variety of low-cost microcomputers for schools and the problems that this diversity of incompatible hardware and software in schools would present. The short-term proposal was that Commonwealth funds be provided for only a small number of computer systems: those on the “recommended list” drawn up by each state (Tatnall and Jenner 1986). Only these would then be supported by the program. Its longer-term proposal was for a development project to design and build an “Australian Educational Computer.” Apart from reinforcing Australian culture, this project would have had the added advantage of the new computer being built in Australia by an Australian company.

Specifically Designed Computers for School Use in Other Countries

Several other countries had already decided to design and build their own school computers. These included the United Kingdom, New Zealand, Sweden, and Canada. The UK and New Zealand developments were essentially by private industry and produced the Acorn BBC microcomputer and the Poly, respectively.

In Sweden it was driven by the government and the major goal was to assist local industry. The process in Canada was rather like that proposed for Australia and resulted in the development and production of the ICON computer (Tatnall and Leonard 2010).

The United Kingdom: Acorn BBC Computer

In the early 1980s, the British Broadcasting Corporation (BBC) started to work on the *BBC Computer Literacy Project* (Schmidt 2010) with its TV series: *The Computer Programme*. The BBC wanted to base this project around a microcomputer that was capable of doing things such as programming, graphics, sound and music, teletext, communications, controlling external hardware, and artificial intelligence (Schmidt 2010). After discussions with several British computer companies, Acorn Computers won the contract to provide this computer (Tatnall and Leonard 2010) which became the Acorn BBC Model A, (Based on a 6502 processor with 16 k bytes of RAM.) and this was shortly followed by the Acorn BBC Model B (This was also based on the 6502 but with 32 k bytes of RAM and extra connectivity.) (Old-Computers.Com 2009). The BBC Model B quickly became very popular in the United Kingdom and was widely used in its schools. It also became quite popular in several Australian states.

The Compis (Sweden)

In 1981 the Swedish government began a program for a school computer (Kaiserfeld 1996) with two goals: to give industry in Sweden an opportunity in the development of new technology and to provide Swedish schools with modern, inexpensive computers. A Swedish computer company was appointed for its manufacture, and although over 25,000 Compis computers were put into schools, it was never a market success, and production ceased in 1988 (Kaiserfeld 1996).

The ICON (Canada)

In 1981 the Canadian Minister of Education remarked that: “The Educational and training systems and the industrial sector must not see themselves as separate entities, but as partners in

Ontario's future ...” (Stephenson 1981). She announced the need for computer literacy of all students and set up an Advisory Committee on Computers in Education (Goodson and Mangan 1992) that would, among other things, draw up plans for an educational computer to become the standard in schools (Goodson and Mangan 1992). This initiative had a dual purpose: to create a microcomputer explicitly designed for the Canadian educational environment and also to stimulate growth in the Ontario and Canadian electronics industries (Verburg et al. 1987). A Canadian company was contracted to build this machine (although later this was later to join with Burroughs).

The computer's functional requirements included high-resolution color graphics and sound synthesis capabilities, 64 k of RAM, and a local area network form of architecture (Goodson and Mangan 1992). The specifications also required it to support Canada's bilingual (English and French speaking) population. The new computer was to be a combined unit with the screen, processor, and keyboard all in a single case. It was also to include a trackball. The ICON system was designed around the 80186 microprocessor and based on a workstation/file server architecture with no local storage on the workstations. The operating system, QNX, was Unix-like. One significant problem with the ICON, however, was that while there was a large amount of available software for the Apple II and the Commodore PET, the ICON was compatible and so needed its own custom-written software.

The Poly (New Zealand)

The Poly was designed in 1980 at Wellington Polytechnic as a teaching machine intended for use in computer-assisted learning (Bits & Bytes Editorial 1982; Smythe 2007) and to fill a niche market in education. Poly-1 was a networkable machine based on the Motorola 6809 processor and came with 64 k bytes of RAM and a video card to display graphics on a color TV monitor (Bits & Bytes Editorial 1982). Course materials were produced and refined by a team of New Zealand teachers for a variety of applications. Poly was presented as “a reliable, robust,

networked, teacher and student-friendly closed system specifically designed to deliver computer assisted learning across curricula as well as computer awareness, computer studies and support for school administration” (Smythe 2007).

Designing the Australian Educational Computer

This then was the background for NACCS' proposal to designing and building an Australian Educational Computer. There were several reasons for developing this computer (Tatnall 2013):

- So that Australian school children would have access to well-designed computer equipment.
- To reduce the problem that US-designed computers such as the Apple II and Commodore 64 came with the burden of imposing aspects of American culture.
- To provide a development and manufacturing opportunity for Australian industry. It was generally supposed that an Australian company such as MicroBee, which produced a CP/M computer used in many Australian schools, would be a likely manufacturer.

The idea was that the Commonwealth Schools Commission be responsible for the production of an **educational user requirement** and an **educational technical requirement**, while the Department of Science and Technology takes charge of the **system concept study**. If no existing computers were to satisfy the educational technical requirements, then the Department of Science and Technology would draw up an **Australian design specifications** and arrange for the manufacture of pilot and prototype systems (Commonwealth Schools Commission 1983).

Determining the Educational User Requirements

An **Educational User Requirement Working Party** was appointed early in 1985, consisting of educators at all levels from around Australia. It soon produced a report (Commonwealth

Schools Commission 1986a) outlining the many and varied potential educational needs of computer users in schools and the need for integration of information technology concepts into the curriculum. Its report highlighted several critical user requirement issues to be taken into consideration by the Educational Technical Requirement Working Party:

- The needs of various different types of users at both primary and secondary schools
- The nature of the physical, school, and classroom environment
- The variety of applications
- A consideration of modularity, expandability, entry cost, user interface, robustness, reliability, portability, compatibility, and adoption of current recognized standards

Determining the Educational Technical Requirements

The **Technical Requirements Working Party** was set up in 1985 as an “expert” committee with membership reflecting the range of relevant groups and interests from each Australian educational sector, state, and territory. The committee’s report to NACCS was published in March 1986 and contained two main sections (Commonwealth Schools Commission 1986b):

- A technical requirement, which gave detailed coverage to user interface, input devices, output devices, processing resources, networks, telecommunications, and system requirements
- A section dealing with possible implementations of these requirements to satisfy at least three envisaged types of use: personal systems, classroom systems, and school network systems

The idea was that these could be catered for by a family of compatible systems having a common user interface and that at some stage in the future, the way should be left open to connect these systems to computing facilities at the district, regional, state, or national levels (Tatnall 2013) (Fig. 1).

The System Concept Study and the End of the Project

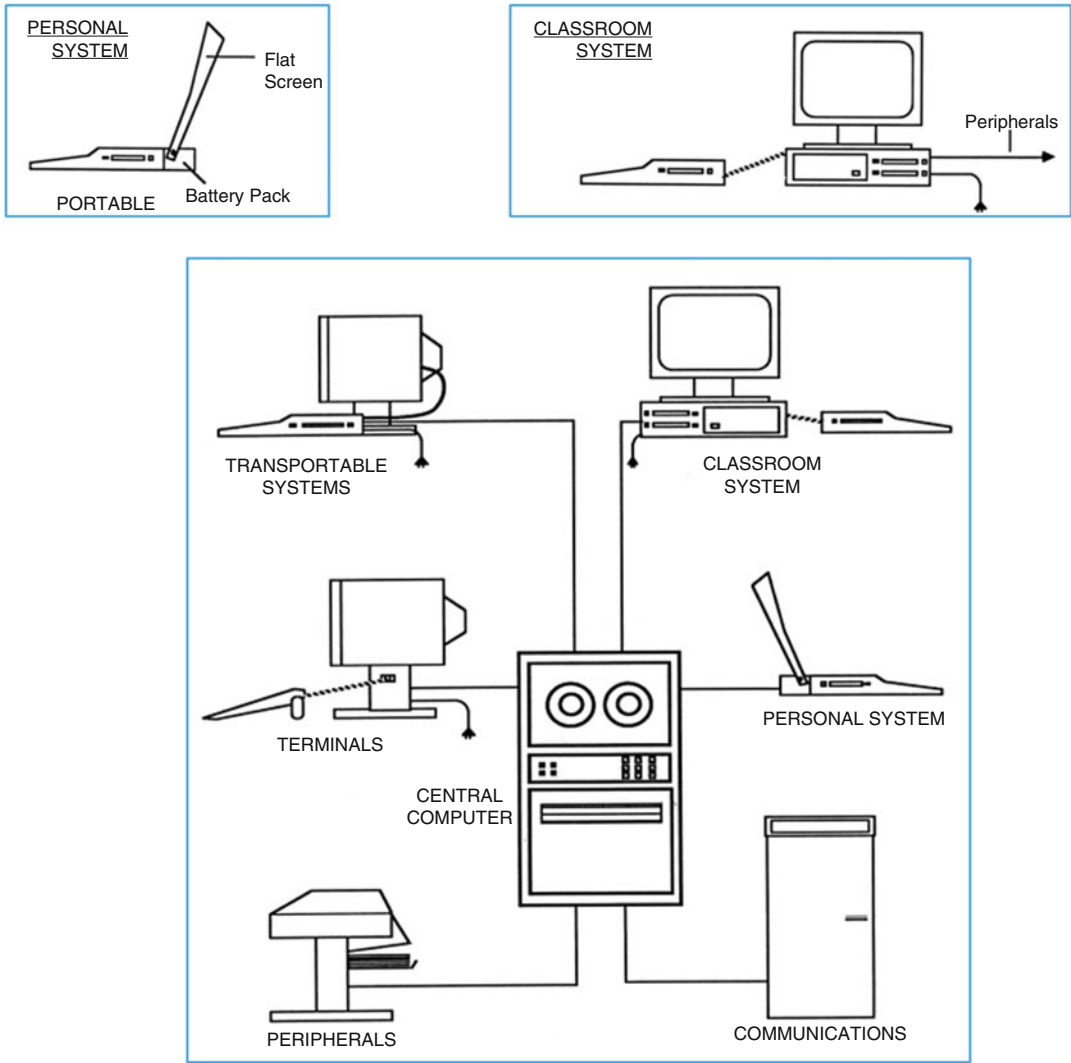
The next steps in the process should have been setting up a system concept study to be followed by a development proposal, but at this stage, the project stopped (Tatnall 2013, 2014). The 3-year government initiative for the National Computer Education Project was at an end and so was its funding. Further development funds from the Department of Science and Technology were not made available, and so work on the Australian Educational Computer ceased (Tatnall and Leonard 2010).

The Bunyip: A Failed Technological Innovation

Innovation can be defined as “the alteration of what is established; something newly introduced” (Oxford 1973), and to be successful, the new technology must be adopted and used. The process of innovation thus involves getting new ideas accepted and new technologies adopted and used (Tatnall 2011), and a new technology will only be adopted if potential users make a decision to do so. With only the two Schools Commission reports to show for the effort expended in designing the Australian Educational Computer, this project could not be considered a success. Actor-network theory (Callon 1986, 1991; Latour 1986, 1991, 1996) could be used to good advantage to explain this failure (Fig. 2).

Like Frankenstein’s monster (Shelley 1818), the Australian Educational Computer was never sufficiently “real” (Latour 1996) to be given a name of its own, but I will call it the Bunyip. (A Bunyip is a creature from Aboriginal mythology that is said to lurk in swamps, billabongs, and rivers.)

The development project for building the “Bunyip” involved the Commonwealth Government, State and Territory Governments, the Commonwealth Schools Commission, the Department of Science and Technology, other State and Commonwealth education authorities, committee members, reports, specifications



Bunyip, The Australian Educational Computer that Was Never Built, Fig. 1 Personal and classroom systems and a possible implementation of a school-wide system (Commonwealth Schools Commission 1986b)

documents, the computer industry, and changes in funding priorities. Various interactions between these actors led to the development of the specifications for this computer, but not to its construction (Tatnall 2013). Getting a technological innovation adopted, or in this case even manufactured, involves convincing people of its value. Convincing other people was almost impossible in this case as, outside the committees and the government, very few people knew about

it. This project really was a team exercise, and no particular individuals stood out or made their presence felt. Perhaps this was a factor in its demise.

Furthermore, at about this time, the microcomputer technology situation changed dramatically with the entry of two new actors into the school market: the IBM PC and Apple Macintosh. When the project was dropped, there was no public outcry – the public did not know about



Bunyip, The Australian Educational Computer that Was Never Built, Fig. 2 Australian stamp showing a bunyip

it. Although we all were disappointed by the decision not to proceed, in light of later developments, we were perhaps relieved not to have created a white elephant like the Canadian Educational Computer – the ICON – which was neither PC nor Macintosh compatible and soon became obsolete. Today the decision Australian schools make in choosing which type of computer to use is between a Windows PC and a Macintosh. Although possibly representing a missed opportunity, the demise of the Bunyip had very little overall impact on computer education in Australia, but it was not entirely a waste of effort as the reports and the specifications documents published by the two working groups are still of value today. Would this project have helped to stimulate the Australian computer industry?

Perhaps if one or more prominent individuals had been prepared to speak out passionately for building the Bunyip, their interestment (Callon 1986) could have assisted it in becoming real, and its future might then have been quite different. This project was about technology, but technology itself had very little effect on its termination.

Conclusion

The dominance, within a few years of the Apple Macintosh and MS-DOS (later Windows) PC, meant that it was probably lucky that the Bunyip project did not proceed and create an expensive white elephant. Perhaps it just comes down to government funding and the establishment of a need for the system. If funding had been available and a successful need established, would Bunyip have been successful? If it had been built, would Bunyip have been able to translate (Callon 1986) to a new form in the face of competition from the PC and Macintosh?

Cross-References

► [Ultraneet](#)

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Business Computing

- [Birth of Information Systems Curricula in Victoria in Colleges of Advanced Education and Universities](#)

Business School-India

- [Knowledge Economy of Faculty Competencies of Indian Business School](#)

BYOD in the Classroom, Opportunities, Issues, and Policies

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Introduction

It is acknowledged that increasingly higher education students are entering the classroom equipped with their personal mobile devices, which they use to connect to the institution network. These students may bring one or more devices, such as mobile phones, smartphones, or tablets, and expect to use these devices for learning purposes. This is a natural process as these devices are part of students' daily lives, and they can easily adapt to their needs and use in the classroom. The widespread ownership of personal mobile technology has given rise to the "bring your own device" or BYOD model where educational institutions encourage students to use their personal devices to support teaching and learning practices both inside and outside the classroom. BYOD, therefore, brings changes to the traditional model where institutions are used to

providing and having more control of technologies students and faculty would use on campuses and classrooms.

BYOD is a significant feature of mobile learning that is stated will go mainstream in education as mobile technology is an integral part of students' lives and essential to their academic success (Brooks and Pomerantz 2017). Another reason for institutions to move towards BYOD is the need to adapt to technological advancements and students' lifestyles, to remain relevant and attract potential students to their programs. Along these lines, due to rapid technological developments, the notion of BYOD will likely expand to encompass wearable devices such as smartwatches and eyewear devices (e.g., glasses) for academic purposes. For example, in comparison with the 2015 survey data, the 2016 EDUCAUSE Center for Analysis and Research (ECAR) survey (Brooks 2016) reported that student ownership of wearable technologies (e.g., smartwatches), and the use of these devices for coursework had increased 150% and 100%, respectively. A further reason for institutions adopting BYOD may be related to their inability to justify costs involved in supplying technology to students, such as computer laboratories and software, when students have their own powerful mobile devices (Sharples 2013). It is also likely that students will prefer to use their devices that are probably newer, better, and more updated than the technologies available at their educational institutions.

The BYOD model is often discussed as providing both opportunities and challenges to higher education institutions. If institutions decide to embrace a BYOD model, then the challenges that can hinder its successful implementation and potential learning benefits must be addressed. The challenges must also be explored with leaders and other parties (Traxler 2016) to develop or update acceptable and supporting policies. The following sections provide a background on opportunities afforded by personal mobile technology followed by a discussion of key challenges related to BYOD, while addressing implications for policies.

Opportunities

A BYOD model can be an attractive option to higher education institutions due to perceived reduced costs, since students use the available technology they own to support academic practices. This might be relevant at times of budget cuts affecting many institutions, which will also impact the provision of resources. It is important to note that while institutions may reduce costs related to less maintenance, and supplying hardware and software to the students, they need to consider financial costs related to improving their network infrastructure capacity to accommodate not only students' mobile devices but also those owned by instructors and staff. Institutions also need to consider costs related to enhancing their network security, by purchasing and upgrading software. Nevertheless, BYOD provides increased opportunities to make more technology available in the classroom, which students can potentially benefit from and develop needed skills for the twenty-first century workforce such as digital literacy skills. In addition, as the devices are available in the classroom, which allow access to online information, sources, and built-in tools and applications, it enables instructors to use those devices in lectures in a variety of ways to enhance the learning experiences.

Furthermore, BYOD offers students more ownership over their learning as they can choose when and where learning will happen, select and customize the tools needed to complete activities, access internet resources and information, and interact with others. Within the classroom, student devices can potentially provide endless learning opportunities ranging from informal to formal usage of the devices. Students, for instance, with an internet-enabled mobile device in the classroom, can search for supplementary sources to enhance understanding of the content being taught, can access videos or take pictures of course materials, complete quizzes, or reach out to experts in the field. Further examples include opportunities for collaboration and participation in instructor-organized activities. An instructor, as exemplified by Song and Kong (2017, p. 42), can

“enact mobile and seamless learning using a project-based learning approach more effectively for the whole course on the learning management system . . . and using different apps such as Google Drive and QR [Quick Response] codes as tools for varied teaching and learning purposes.”

Key Issues and Policies

Despite the opportunities and potential educational benefits, as with any new technology in education, a BYOD model brings its own challenges that can compromise its effective implementation in higher education. The following sections discuss some of the key challenges often mentioned by educators, researchers, and practitioners. While addressing the challenges, the sections also discuss implications for policies.

Inappropriate Use

A widespread concern among instructors relates to disruptions and distractions caused by personal mobile technology. It is common knowledge that during lectures, students use their devices for both academic and nonacademic purposes. While students can be using their devices to take notes or access extra resources related to content, at any time, they may also access social media or other applications to engage in nonclass activities, which may disrupt the class, participation, and student learning. Engagement in nonclass activities such as texting and browsing the internet may lead to instructor reluctance to adopt BYOD, or the implementation of strict policies that ban or limit the devices in class. These types of policies are counterproductive, given the learning opportunities and experiences provided by a BYOD model. Since students will not give up their personal devices, a more positive approach involves developing or adapting existing policies that help decrease the disruptions in the classroom. Considering that students and instructors may have different viewpoints in relation to the value and use of mobile devices in the classroom, more effective policies are those developed in consultation with students, instructors, and other stakeholders on

the appropriate BYOD usage and practices in the classroom, which will meet the needs and expectations of the involved parties.

A policy is needed that encourages regular and updated workshops, seminars or professional development to promote awareness, technical skills, experimentation with pedagogical innovations, and good practices of teaching and learning with technology, as well as exploring examples of BYOD activities, tools, and applications for academic purposes. The planning of these activities should be informed by research outcomes in the field, practical experiences, and understanding of students' practices with their mobile devices both inside and outside the classroom.

Institutional support is crucial to help instructors to address the challenges of today's digital classroom and integrate meaningfully the devices students carry with them into their teaching, adopting innovative pedagogical practices based on learning theories and student-centered approaches that promote engagement with content and activities. Research has shown that when instructors create a classroom environment that encourages active participation, it helps reduce the possibility that students will be causing disruptions with their devices (Berry and Westfall 2015). Similarly, Brooks and Pomerantz (2017) exemplified that students who used their smartphones purposefully to complete in-class activities, which also involved instructor-led activities, were less likely to use their devices to engage in nonclass activities. Moreover, instructors' engagement in professional development and experimentation with mobile technologies can help change their attitudes towards disruptions (Dyson et al. 2013).

Digital Inequalities

Despite widespread mobile technology ownership, it is not universal. For example, in comparison to developed nations, the Pew Research Center (Poushter 2016) reported that emerging economies lag behind smartphone ownership; however, according to the survey results, in a number of emerging and developing countries, more individuals are connected to the internet,

and smartphone ownership is climbing at an extraordinary rate. On the other hand, in some of these countries, there may be issues related to cost of internet access to maintain connectivity, and low bandwidth, which can restrict the use of online sources, downloading files, or other activities.

Therefore, a BYOD model can give rise to issues of digital inequality, preventing some students from participating in mobile-based educational opportunities. It can potentially exclude students, for instance, who either do not have access to the latest technology, applications and internet connection, or do not have access at all to a device to be able to participate in the learning activities. In addition to digital access, students can also be disadvantaged if they do not possess the knowledge and skills to effectively use the devices as learning tools.

There is certainly a need for a policy that will address equity issues unique to BYOD. In the same vein, Traxler (2016) reminds us that any policy must recognize that mobile technology is unlike other technologies in terms of equity that requires access to hardware, tools, applications, and ongoing internet connectivity. Policy needs to address the variety of mobile devices students bring to the classroom, with different operating systems (e.g., Android, iPhone), some more advanced than others, which have implications for participation in activities. Instructors, for instance, may not be able to use an application (app) that does not run across the different operating systems. Therefore, they must develop awareness through workshops or training of academic applications that will work across different mobile platforms or consider alternatives such as browser-based activities or cloud computing if all students have internet connectivity on their devices. Activities may include web-based response systems where multiple devices can be used to answer quiz questions, or access Google apps such as Google documents, and storage of data using any device and from any location.

As hardware and software keep developing and improving, the challenges related to instructors not being able to organize activities due to

different mobile operating systems should soon be resolved with device-agnostic applications. Therefore, despite the diverse BYOD environment, the software can be homogeneous, meaning that students owning iPhones or Androids, can run the same application or activity on both devices (Norris and Soloway 2015), avoiding disadvantaging any student inside or outside the classroom. The idea of device-agnostic facilities reinforces the need for a policy that considers frequent delivery of workshops to allow instructors to keep up with technological developments and new opportunities. Independently of technological advancements, prior to planning activities supported by BYOD, it is critical that instructors conduct a needs assessment to learn about student devices and relevant technical limitations to promote equity in the classroom, and beyond. This is paramount as, for instance, learning activities may be organized in the classroom but will extend to other contexts, later returning to continue in the classroom. In this case, instructors need to make sure all students will have access to a functional and internet-enabled mobile device.

Information Technology Issues

Effective BYOD implementation will certainly require robust network infrastructure to support teaching and learning practices, which has financial implications for institutions. Institutions will need to adapt their existing policies to accommodate the BYOD model that relies on multiple connections and 24/7 connectivity to meet student and instructor expectations and needs. Song and Kong (2017, p. 43), for instance, reported that “due to unstable internet connection and the slow data transmitting speed, they [instructors] felt disappointed, even annoyed when using BYOD in their pedagogical practice. This slowed down the lesson progress and discouraged them from using BYOD in class.” Thus, lack of reliable and stable internet connectivity does not only lead to frustrations but also prevents students from participating in learning opportunities. It is important to note that a policy addressing network infrastructure needs to be sufficiently wide, yet detailed, to allow emerging technologies such as

wearable devices and the “Internet of Things” that connect any device to the internet.

Furthermore, multiple devices are available in the classroom and, as mentioned previously in this entry, with different operating systems and applications, which may complicate the provision of technical support. Information technology (IT) personnel, used to managing and supporting controlled technologies provided by their institutions, may face challenges to support a potential unlimited number of technologies and models owned by the students (Traxler 2016), which they may not be familiar with. On the other hand, students are familiar and comfortable with using their everyday mobile devices and would know how to work with their devices and fix technical problems. Students, as emphasized by Brooks and Pomerantz (2017), may figure out solutions for the technical problems on their own, or search for online resources such as YouTube videos that teach them how to solve problems related to their devices, or use their friends or network who can help them fix the problems.

The issue of whether institutions will provide technical support or not for student personal mobile devices is debatable, ranging from some educators arguing that support should be provided to transferring the responsibility to the students for repairing and maintaining their devices (Santos 2015). There may also be financial implications related to technical support as institutions may need to hire more IT personnel since the workload may increase. Therefore, institutions will need to define a clear policy that states what kind of IT support is available to the students.

A further challenge widely discussed is that the BYOD model can bring about a series of security concerns. It is likely that traditional measures and procedures previously adopted by institutions to secure access to their services and information will need to be revised to minimize risks. Security risks may range from the devices bringing malware and viruses to the institution network, which can freeze the system, and lead to theft of institutional data, to loss of unprotected mobile devices containing institutional

information (Santos 2015). Strong policies will be needed to secure the institutional network, systems, stored private and sensitive information in addition to implementing on-going measures to enhance security systems. Security measures employed by institutions are currently varied, ranging from registering personal mobile devices, which enables tracking the activities performed by these devices, implementing a dedicated virtual network to BYOD separated from the institution network that store private data and applications, to enforcing strong authentication mechanisms such as student and instructor passwords.

To be more effective and comprehensive, policies related to security should be developed through different departments including those for IT and Human Resources to ensure alignment and coverage across departments. In addition, students should be involved in the development of security policies to promote more commitment on complying with the policies. Policy should additionally address frequent training for students and instructors to help them understand the institutional policies, develop awareness of security threats, and learn strategies to decrease potential risks. For example, training sessions could cover why software should be installed and updated on devices and the importance of setting up passwords.

Conclusions

A BYOD model can potentially bring benefits to higher education institutions ranging from reduced costs to learning and teaching opportunities both inside and outside the classroom. There are key challenges attached to this model that can hinder its successful implementation, including inappropriate use of personal mobile technology in the classroom, digital inequalities, and information technology issues. These issues must be addressed to support effective BYOD implementation, which aim to enhance teaching and learning practices. To address these issues, institutions will need to either update their existing policies or

develop supporting policies that are unique to BYOD, or consider a combination of both approaches.

While the issues discussed in this chapter are not unique to one country in particular, policies need to be developed taking into account the culture, context, the institution itself, departments, and, necessarily, course level needs. Effective policies should be developed in collaboration with key stakeholders from the institution, including administrators, students, instructors, and information technology personnel to address the issues discussed in this chapter and beyond. Beyond this, technology keeps developing at a rapid pace and will certainly bring other challenges and concerns. Therefore, policies must be flexible to accommodate the rapid technological advancements that will expand the notion of BYOD and will impact, among other things, usage, attitudes, behaviors, and the need for innovative teaching and learning practices. Finally, BYOD policies need to be informed by research findings in the field, by practice and experiences, as well as needs assessment conducted with students and instructors.

Cross-References

- [Mobile Computing and Mobile Learning](#)
- [Mobile Learning](#)
- [Mobile Learning and Ubiquitous Learning](#)
- [Tablet Use in Higher Education](#)

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► [Programming Languages for University Courses](#)

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► [Programming Languages for University Courses](#)

Camera Technology

► [Capturing Learning Through Mobile Device Cameras](#)

Cameras

► [Educators and Children Perceiving Affordances with Working Technologies in Early Childhood Settings](#)

Capacity Beliefs

► [Gender Difference in Self-Efficacy for Computational Thinking in K-12](#)

Captions

► [Assisting People Who Are Deaf or Hard of Hearing Through Technology](#)

Capturing Learning Through Mobile Device Cameras

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Synonyms

[Camera technology](#); [Constructivism](#); [Digital portfolios](#); [Education technologies](#); [Evidence-based learning](#); [Mobile devices](#)

Definition

Mobile devices today include a camera that offers the functions of both still photos and video recording. These functions were once seen as expensive and difficult to involve in learning. Now, learners have access to take photos, video recordings, and edit and publish all within one device. When camera technology is used in the classroom, it can promote valuable learning outcomes and higher-order thinking and develop traditional

and new literacy skills (Henderson et al. 2010; Schuck and Kearney 2006).

Mobile devices and laptops have become popular tools to harness technology in education. Digital technology has the potential to create an environment that is student centered as it allows access to learning through a variety of modes and resources. The inbuilt function of a camera offers educators to drive opportunities that support students to demonstrate learning, self-reflect, and provide feedback. Pedagogy practices will affect the integration of digital technology.

Introduction

Creative and effective integration of technology needs to be married with new pedagogical practices. The power of technology is driven by a teacher's pedagogical practices. For example, technology will support and aid in the implementation of a constructivist paradigm (Prensky 2008). The teacher's role is not to feed knowledge but demonstrate how to develop and find new knowledge. Teachers should see their facilitating role as a supportive, intellectual role. They can be there to support digital literacy skills and ensure the function of technology is applied appropriately. They are the experts in supporting literacy skills and integrating technology and tools correctly (Shaikh and Khoja 2012).

If teaching pedagogy does not change, technology will not be used effectively. Traditional teaching methods of teacher-centered and controlled lessons do not appear to create innovative, lifelong learners. Delivering information within a teacher-centered environment is not effective when it is mediated through technology (Shaikh and Khoja 2012). The teacher's role is a facilitator because when teachers are still relying on lecture style teaching, technology hinders the learning environment for students (Prensky 2008).

Constructivism emphasizes that learning is student-driven. Learning is active through knowledge construction, conversation, articulation, communication, collaboration, and reflection (Shaikh and Khoja 2012). Prior knowledge is

used to help discover new concepts rather than students being told what to learn. Students become engaged in their learning, and the teacher plays a vital role to shape these learning conditions (Collis and Moonen 2006).

When integrating the technology, teachers should not primarily focus on the integration of apps. "There's an App for that" is a saying that implies education can be driven through a digital platform. The focus of finding apps to reinforce and drive learning moves away from the teacher's role and makes the assumption that apps can replace the teacher and skills that are essential for today's learning environment. The emphasis moves away from student-driven work created by technology that may not marry with open-ended tasks to create stimulating research.

Learning Environments

In today's learning environment, it is imperative to provide multiple opportunities for students to engage in their learning and promote learner ownership and voice in the learning process (Oliver and Herrington 2001). The camera within mobile devices provides these opportunities. The integration of mobile technology does not need to focus simply on external apps, websites, and software. Teachers need to recognize the potential of the inbuilt functions found in digital devices that can help support constructivist paradigm.

Students and teachers collaborate to create personalized learning environments that generate creative, meaningful learning. Student's roles in the classroom need to be active roles, one which is supported by collaboration, conversation, dialogue, and sharing of knowledge to open up new and exciting ideas (McLoughlin and Lee 2010). Teachers provide opportunities for the learners to find relevant information, to work in groups and share ideas, and to validate knowledge.

Technology provides opportunities for learning and investigating that will give learners the knowledge and building blocks to become successful, lifelong learners. Digital technology allows students to find this information and

explore multiple resources. It allows learning through multimodal learning, using a range of resources to research and problem solve. It gives students opportunities to collaborate inside and outside the classroom. Teachers need to reconsider their pedagogy to ensure students are active participants and co-producers of their learning. Technology provides access to information. Being passive consumers of prepackaged facts will not support the wider potential of lifelong learning (McLoughlin and Lee 2010).

Communication facilitates students' ideas, information, and emotion. Still and video-based photography can provide multiple opportunities for student engagement. This technology can be used as an analyzing and observation tool to enhance learner performance. Using digital video as a tool can support reflection of student learning (Henderson et al. 2010; Schuck and Kearney 2006).

Valuable learning outcomes have been related to the use of video productions. Higher-order thinking skills have been present in the use of videos. High-order thinking skills include problem-solving, reasoning, planning, analyzing, creating, and questioning skills. Through using these productions, learners become aware of the process of learning and have the potential to reflect on their learning. They develop the necessary skills to identify how they learn and why they are learning (Henderson et al. 2010).

Applications

In the past, issues such access to digital cameras, access to photos and storing of photos and post-production editing, and creation hindered the integration of still and digital photography (Henderson et al. 2010). These issues no longer exist due to the inbuilt camera and abilities of current digital devices.

While the following sections specifically focus on the iPad Air, other digital devices offer similar properties. The iPad Air embeds a 5-megapixel iSight camera, offering HDR photos and videos. Functions within the camera setting are simple

and easy to use, and users have access to multitude of functions that are easy to navigate and use. The design of the camera allows for a simple, quick transition between still photography and videoing. Users push one button to capture a photograph or commence video recording. Autofocus assures the user and takes away any manual complications of photography. At the push of a button, information has been captured. Users can navigate the screen with the simple large design buttons.

Photographs and videos are automatically stored within the iPad and offer quick access. Editing tools such as rotation, crop, filters, and enhancement of colors and red eye reduction are easily accessible when capturing a photo or video and occur with one tap of a finger. Sharing of photos has become even easier as the functions of the iPad allow multiple options for sharing such as links to open in another app, email, message, social media, copy, print, and photo stream through iCloud.

Still photographs give authentic opportunities for evidence of learning in the classroom. Teachers can use video recording to monitor the development of literacy skills such as reading. Students can video themselves participating in classroom activities and reflect on their participation and learning. These videos can be used as a form of communication, within the classroom and with the wider community such as parents and carers. Students collect and collate evidence of their learning and create digital learning portfolios. Digital portfolios can be created to give students the opportunities to reflect on their learning process. This will give them opportunities to share what they have learnt and how they have learnt it.

The camera function has been a valuable resource to capture student learning. Camera technology has enable students to showcase their work and development of learning within unit topics. The camera has been a valuable resource that has been adapted to meet the needs of all students – from Foundation to grade 6 primary school students. Due to the fact the camera captures the work of the student, it has the potential to complement the work produced, regardless of their age. Digital portfolios have been a key to

capturing ongoing learning within a lesson or series of lessons in primary classrooms from Foundation to grade 6. The following sections related to practice, observations, and research in one primary school.

Within the junior primary levels, the camera is a function that can be used in most lessons. It is a valuable tool to showcase ongoing student learning and achievement. Foundation students were introduced to the camera and have used it as a tool for learning since commencing the school year. Throughout the year it has assisted teachers to monitor student learning and progress without having to rely on written responses from students. By implementing camera technology into these classes, students have been able to articulate their learning and have a record of their learning. Rather than depending on written responses, teachers have captured more learning by allowing students to reflect and articulate their learning through audio responses to questions, evidence of learning through photographs and articulation of their learning through video examples. Such record would otherwise not be available due to the lack of literacy skills of most Foundation students.

To help support the development of the skills associated with using the camera function, teachers in Foundation classes were supported with assistance from the digital technology leader. The institution and leadership is one of the four key components that impact on the integrations of technology. Without the necessary support and understanding of how these components work together, technology has the possible effect of limited integration (Collis and Moonen 2002).

Introduction to the camera and digital learning portfolios commenced through small-group guided reading and writing sessions. The teacher and digital technology leader guided the students to participate in a conversation that discussed the purpose of digital portfolios. Students discussed the features of texts and were guided to generate a title for their digital book. This activity gave ownership to the students and an understanding of how their digital book will be used at school and how it will be different to hard copy books (that it

would contain videos and pictures of their learning). Students generated the title and drew a picture on the front cover. The technical skills of taking a photo and adding it to their book were the initial skills taught to the students.

Team teaching was used to get the Foundation students confident and knowledgeable with using the technology at school. Over three 1 h sessions, two teachers worked with a small group of students to show them the technical logistics of the iPad. These sessions were shorter than expected due to the fact students picked up the skills quicker than expected. The extra support given to the classroom teachers was a critical factor to build student knowledge and confidence to use the device and camera independently.

Within the grade 1 and 2 classes, it is common to have an iPad camera accompanying a mathematics session. A fundamental part of mathematics in the junior grades is to use concrete material to show learning. Students will take a photo of their learning or a video recording explaining the work they have completed using the materials they manipulated. Prior to this, students were unable to keep a record of their work if it was created out of concrete materials. Drawings and hardcopy interpretations were previously the only way to keep copies of work completed when using concrete materials. Although at times, the hand drawn copies were not true reflections of the work they had completed. Since the introduction of cameras, video footage shows the work students have completed with them articulating their learning using correct mathematical language.

Although student reflection is seen as one of the most powerful learning tools for learning outcomes, it is rarely used in classrooms in conjunction with this technology (Henderson et al. 2010). Students can utilize the camera and the technology as tools for self-reflection, but usually requires a suggestion from the teacher.

Over the course of a term, the camera was an integral tool to assist in the creation of daily learning reflections in grade 5 and 6 classes. Photographs showed the development of the learning and building throughout the project and video

recordings were used as reflections and progress of their learning. These reflections were student led with students discussing their learning. In their videos students discussed learning opportunities and “learning hurdles.” They discussed what they had discovered during the session and what problems (hurdles) they had faced. Students self-reflected on the way they could solve these learning hurdles. This reflection ensured they were ready for the next session with solutions to issues and problems, and they knew the direction for their future learning.

The platform used to collect the work and create digital learning journals was Book Creator. The app was chosen due to the simplistic functions and layout used to create books. Students created their own books that related to their learning. The emphasis was on the student actively inputting information which was appropriate to their learning needs. This supports a constructivist paradigm as the app is student centered, allowing learners to make choices throughout the learning process, to reflect on their learning, and to communicate new ideas and knowledge (Oliver and Herrington 2001). Students obtain the relevant information and then build knowledge to solve problems or work through a task. The teacher provides the scaffolds for students to participate in higher-order thinking, problem-solving, and decision-making (Oliver and Herrington 2001).

Summary

These ideas can be used as an example of student learning and engagement through harnessing the use of an inbuilt camera. The capabilities of digital technology go beyond the use of and emphasis of outsourced resources such as websites, apps, and digital programs. When integrating mobile and digital technology, inbuilt functions should not be overlooked. The camera in an iPad offers photography and video recording. This technology can provide multiple opportunities for student engagement and promote higher-order thinking. The uses of this technology can be used as an

example of how to integrate technology into the classroom that promotes high degrees of student initiative.

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Case Study Research

- [Computer-Based Training and School ICT Adoption, A Sociocultural Perspective](#)

Case-Study

- [Ethics and Learning for Teacher Trainees, Team-Based Simulations in Cases of Bullying in School](#)

Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption

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Synonyms

Computer-based assessment; eExams; Equivalent year level scaling; MAPLE computer algebra system; Measuring impact of innovation; SAMR educational model; TPACK framework for technology in education; Transformation of learning with computers

Educational Expectations

Conventional educational attainment expectations for school students are generally defined by curriculum documents in each jurisdiction. However, new technologies disrupt societies, so it is pertinent to ask how computers have changed educational expectations. Robert Heinlein put this into perspective in a short story (1957). The protagonist is Holly Jones. She is 15 and a spaceship designer: “I’m very bright in mathematics, which is everything in space engineering, so I’ll get my degree pretty fast. Meanwhile we design ships anyhow. I didn’t tell Miss Brentwood this, as tourists think a girl my age can’t possibly be a spaceship designer.” This demonstrates some early aspirations of how education might change in future where lunar habitats become well established.

Outside education, business process reengineering is the practice of re-designing work, particularly when using new technology to reduce costs (Davenport 1993). Davenport commented on the role of computers in changing business practices: “...Information and IT are rarely sufficient to bring about the process change;

most process innovations are enabled by a combination of IT, information and organizational/human resource changes” (p. 95).

When we look at societal use of computers, we see large changes. Banking and travel are usually identified as areas of activity most changed by the application of digital technologies. Internet banking, crypto-currencies, and online commerce have greatly reduced the need to visit a bank branch. Similarly, travelers can book their own flights online, and arrange hotels and tours the same way. Digital technologies are a growing digital component in global trade, with the world’s top six largest companies digitally dependent (Statistica 2018). Four of the top 50 firms by revenue are also digital companies.

Ranking of the companies 1–100	Market value in billion US dollars
Apple	926.9
Amazon.com	777.8
Alphabet (Google holding company)	766.4
Microsoft	750.6
Facebook	541.5
Alibaba (online sales site)	499.4

There is therefore a contrast between expectations of educational change and actual change in the commercial world. The commercial world is the one into which school students will grow. Therefore, educational leaders have an imperative to grapple with this growing schism.

The Challenge

This dichotomy provides a significant challenge for educational theorists and researchers. There have been two noted responses by theorists, the TPACK framework and SAMR model. Koehler and Mishra (2008) introduced TPACK as a way of looking at the key role of technology when teaching online. However, this focused on the method of teaching, not the content. Puentedura (2012) went further and theorized that computers would first substitute for common tools (e.g., keyboard replacing a pen), then augment those tools. Later,

in a transformation phase, the computer would allow for significant task redesign, leading to redefinition of learning to that which was previously inconceivable. This transformative perspective was predicted by Downes et al. (2002, p. 23) and aligns with Fluck's three phase model for ICT policy development (2003, p. 139).

The challenge for researchers arises from the need to measure change. Educational research frequently looks at proposed interventions, generally with the intention of improving learning. Two classical kinds of measures are preferred for this kind of work. The first is null hypothesis statistical testing, with a *t*-test or similar used to confirm a new process makes a difference to learning when compared to previous processes. The significance of such a correlation measure is established by a *p*-value, which demonstrates the unlikely possibility of the result being accidental or by natural variation.

The second class of measures of improved learning includes effect size. Lopez et al. (2015) stress the importance of citing the effect size, because this dimensionless measure is independent of sample size. Effect size can be calculated in several ways: Cohen's *d*, using the pooled standard deviation of the control and experimental groups is most commonly found when conducting *t*-tests; partial eta squared has mostly been reported in studies using ANOVA; adjusted R^2 has been associated with regression analyses; and Hedges's *g*, which applies a correction for small samples (Lopez et al. 2015, p. 108; Tamim et al. 2011). Effect sizes for the use of computers in education have been quite modest with "the average effect size ranging between .20 and .47 standard deviations" (Karasavvidis 1999, p. 2). Effect size calculations are predicated on the test scores being distributed in a near-normal way and on the standard deviations for pre- and posttests being similar.

With transformative applications of computers in the SAMR model, educational researchers have a difficulty in identifying a common scale from which to calculate the effect size of a learning innovation. Following the TPACK framework, if the researcher is using a computer to teach the

same content in a new way, then a standardized and calibrated assessment of educational achievement can be administered to both the control and experimental groups before and after the intervention, with the Solomon four-group design overcoming external validity weaknesses caused by pretest sensitization of subjects. In such research designs, the implicit assumption is the pre- and posttests will accurately measure student educational achievement at a point in time.

For transformative applications of computers, the radically different educational content may be such a departure from the conventional curriculum that students will have no prior knowledge whatsoever. This does raise an ethical question concerning the emotional impact of a pretest assessment in which virtually all students will likely have a negative experience. The research design parameters violate simple humanity, so methods are sought which give the required validity and yet provide a positive emotional experience to the research subjects.

Using Computers in Assessment

There is another aspect of teaching new content which is impossible to deliver without computers: assessment. If computer use is transformative, it will be essential in assessment (Fluck and Hillier 2017). This also makes the pretest/posttest paradigm difficult. If the learned skills can only be realistically demonstrated through student computer use in the posttest, then protocols would dictate the pretest should also depend upon the same mode of assessment. A complication might be the interference effect of the operational skills required to use the software intended for use as part of the educational intervention to be studied. If operating this particular software is in fact an element of the intervention, then its inclusion in the pretest is contraindicated.

The difference in modality of testing became a matter of national concern in Australia in 2018 when standardized testing in schools was conducted both on paper and on screen. Approximately 20% of school students undertook the

testing on screen. Severe doubts were raised about the comparability of the results from the two modes, with the testing agency “acknowledging that year 9 students who sat the writing test online performed better on average than those who completed the traditional pen-and-paper version” (Robinson 2018). The testing agency subsequently released the results using a common mean scale score and reported effect sizes for any differences over time (Australian Curriculum, Assessment and Reporting Authority 2018). This demonstrates national bodies are aware of the modality issues, and map test scores onto a common scale to allow effect sizes to be calculated.

Possible Solutions

Puentedura (2012) has reported transformative “redefinition” uses of computers in school education with an example effect size of 1.563 (Salomon et al. 1989). This is in the context of an average or hinge effect size of 0.4 for educational interventions (Hattie 2009). The Salomon et al. effect size of 1.563 provided the greatest impact in Hattie’s list of meta-studies “Teacher estimates of student achievement.” Salomon et al. used a research design with three randomly selected parallel groups of students. All subjects were pre-tested with a group-administered standard test of reading comprehension (p. 622). Posttesting comprised a metacognitive reconstruction task, another version of the reading comprehension test and a delayed essay writing task. The researchers undertook structured equation modeling and did not actually calculate the effect size. This was drawn as Hedges’ g from the meta-study by Pearson et al. (2005). Puentedura’s reliance on this study and meta-analysis was criticized by Hamilton et al. (2016).

The Salomon et al. study is useful because it points to a multiplicity of achievement tests both at the pretest and posttest stage. The research design explicitly used a different version of the reading comprehension test for the posttest. This technique is sometimes used to avoid memorization – where the student recalls the same item on

the pretest and responds to the posttest informed by that recollection. Test design can be influenced by the choice of item-response theory or Rasch modeling. Item response theory allows test elements to be analyzed for difficulty, which assists when collating scores. Rasch modeling goes further and allows scores to be mapped onto the same invariant scale. We can presume that Salomon et al. mapped the results of the different reading comprehension tests onto a common scale to allow meaningful comparisons. In a similar way, transformative educational computer-based activities may need a different posttest to calculate an effect size.

One possible way forward in transformative or redefinition applications of computers in education is to look at learning achievement in terms of years of schooling. Normally, an effect size of 1.0 corresponds with a change of one standard deviation (Coe 2002, p. 3). Glass et al. (1981, p. 102) have asserted that an effect size of 1.0 corresponds to the normal learning achievement in a year in elementary school. However, Wiliam (2010) found this relationship varies according to the age of the student, becoming smaller for older year groups. Learning progression reduced from one standard deviation per year in Grade 4 and reduced to 0.27 in Grade 8 (p. 116).

There are perhaps two justifiable ways forward. Where the transformation involves learning material relevant to a higher chronological age than that of the student subjects, Wiliam’s progression could be used to measure the impact in terms of years of advanced standing. This faces a minor problem in that Wiliam’s progressions differed slightly for Mathematics and Reading, so the alignment between age and maturation is not precise. The other possible way forward is to map both pre- and posttest results onto a curriculum-age scale. A curriculum-age scale is one where each item of learning is situated in a particular schooling year and is the way most curricula are presented. If the transformative intervention aspires to teach material 3 years in advance of the chronological age of student subjects, then this would be the point on the curriculum-age scale indicated by test scores. Such an approach

allows for the pretest and posttests to be different, since each test points to a different age level on the scale.

Practical Example

The Calculus for Kids project (Chin et al. 2017) epitomized this transformative approach, asking Year 6 (12-year-old) students to learning how to solve real world problems using integral calculus, with MAPLE computer algebra system software as an aide. This skill is not normally taught until Year 12, so the posttest used items from 1st year university examinations of integral calculus (presumed to be Year 13 on the curriculum-age scale). Key to the assessment of learning achievement in this project was student computer use.

As shown previously, the method of calculating effect size varies between studies. Robust research designs rely upon the same pre- and posttest to determine the effect size of an intervention. However, other methods are also used. Tamim et al. (2015) cite a large effect size of 2.066 for a study of tablet use (Huang et al. 2014). Huang et al. (2014) used different pre- and posttests containing 26 and 14 multiple-choice questions, respectively, but validated these through Cronbach's alpha (α , for reliability) and an expert review group for validity. In consideration of these factors, the researchers resolved to aim for a large study and used Cohen's d for reporting the effect size.

Approach

Traditionally, students have been taught how to find the integral of a mathematical function using a series of rules deduced from first principles. This helps students to understand how to integrate a new function in the future. However, as the catalogue of integral functions grows, the use of poorly memorized results using "first principles" can impede practical calculation. Therefore, professional engineers use a variety of specialist software to "crunch the numbers" although they also need to understand the process and its application to obtain sensible and accurate results. One might

argue that reliance on computing equipment in engineering is analogous to the widening use of word processors in newspaper offices in lieu of pens. There is certainly a discussion to be had about the way these technologies redefine the underlying skills or their acquisition.

The main conceptual tools for the study were Rogers' theory of innovation adoption (2003), the nontemplate problem-solving method of Allen (2001), a realistic mathematics education approach (Gravemeijer and Doorman 1999), and a methodology developed for the transformational use of ICT in school education. This methodology combines professional software tools with multimedia instructional materials. The project therefore set out to answer the following research question:

RQ1: What is the effect on learning achievement of transformational computer use in one mathematical education topic for Year 6 students?

Method

Participating schools were recruited from five Australian states, ensuring a wide range of locations and socio-economic backgrounds. Local facilitators were chosen by each participating school and attended a training session at the University of Tasmania. The training course for facilitators inducted them into higher-level mathematical areas, by taking them through the student learning materials consisting of colorful multimedia animations. In each package, teachers were provided materials for 12 1-h modules to be taught over 6 weeks with links to worked examples in Maple worksheets and extension activities for students to autonomously consolidate learning.

The Calculus for Kids learning module was designed for Year 6 students in their regular classes where everyone could use a computer for each lesson. Schools with both 1:1 laptop classes and computer laboratories were included in the study. Our initial preference was for situations where every student used a personal laptop computer. If this was taken home each day, that promised additional time on task. However, this ideal was not

always met, and some classes were able to access the learning module in a school computer laboratory at specific timetabled sessions. Maple was selected as the supportive software because several of the researchers were familiar with it; to ensure students were not disadvantaged in future mathematics learning (it uses conventional notation); and because the study was supported by an industrial partner in the research (Maple 18-2016).

The students in this study were randomly drawn by each participating school. Given that in most cases an existing class was selected, the regular teacher often agreed to be trained as the facilitator in our methods. The classes reasonably represented students across Australia at this level, without bias as to rurality or social advantage (Table 1).

The ICSEA (Index of Community Socio-Educational Advantage) is a scale of socio-educational advantage that is computed for each school (Australian Curriculum, Assessment and Reporting Authority 2015). The ICSEA is constructed so the median score is 1000 with a standard deviation of 100, and incorporates parental occupation/education, remoteness, and indigenous proportion of students. Lower values represent greater educational disadvantage.

The study used published data on numeracy skills at each school (NAPLAN) as a proxy for aptitude on a curriculum-age scale. This took the place of a specific pretest. The posttest positioned students onto the same curriculum-age scale. It

was designed by one of the authors, a nationally awarded teacher of university engineering, and used items from 1st year university engineering calculus examinations.

Results

Between June 2010 and April 2016, 434 students in 23 classes at 19 schools in 5 (of 8) Australian states completed the Calculus for Kids learning module. The module was taught in Tasmania, Queensland, Victoria, South Australia, and New South Wales. The students were selected to be in Year 6, generally the final year of primary school (changes in Queensland meant the Year 7 cohort moved from primary to secondary school during the period of the research). The mean age of students was 11.96 years, with the youngest 9.97 years and the eldest 13.82 years.

Analysis showed there was a small but significant difference in posttest scores for male students ($M = 13.30$, $SD = 0.39$) and female students ($M = 13.38$, $SD = 0.33$; $t(432) = -2.166$, $p = 0.031$, two-tailed). So, the male students appeared to perform less well. However, when the pretest curriculum-age scale levels were subtracted from the posttest curriculum-age scale levels, the gender differential became insignificant: $t(432) = -1.38$, $p = 0.169$). There was also a small and positive correlation between school ICSEA value and student posttest curriculum-age scale level ($r = 0.168$, $n = 434$, $p = 0.000$), with higher levels of social-economic status and geographical advantage value associated with higher levels of student achievement. This corresponds with expected findings; the correlation is small though significant.

Calculating an effect size for transformative interventions such as this presents several methodological difficulties. Traditionally, effect size is calculated as Cohen’s d based upon the difference in achievement obtained from the same or calibrated pre- and posttests. As previously stated in this study, there were strong pedagogical reasons for omitting any pretest, so NAPLAN results were used instead. The following achievement results were obtained from the project (Table 2).

These values give an effect size based on Cohen’s d of 22.19. This is extraordinarily high,

Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption, Table 1 Demographic data for Calculus for Kids

Variable	Value
Males	235
Females	199
Total students	434
Minimum ICSEA	873
Maximum ICSEA	1197
Mean ICSEA (s.d.)	1042 (82)
Mean age on the day of the posttest (s.d.)	11.96 (0.74)
Minimum age	9.97
Maximum age	13.82

Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption,
Table 2 Student achievements for Calculus for Kids

	Mean	Standard deviation	N
Year level on curriculum-age scale – pretest	6.55	0.24	434
Year level on curriculum-age scale – posttest	13.34	0.36	434

since an educational intervention is considered significant if it has an effect size greater than 0.25 of a standard deviation using a “rule of thumb” (Tallmadge 1977, p. 34) or 0.4 (Hattie 2009) using Cohen’s *d*.

Discussion

The effect size is very large (>0.8) (Cohen 1988). This finding is important, because much research to date has compared the impact of computer use on learning the same content without computers. When contemplating significant curriculum reform built on an assumption of universal computer access, this very large effect size provides evidence in support of a transformative approach.

The outcome from this project has provided evidence that children as young as 10 years old can use computers to demonstrate higher order thinking when freed from contemporary curriculum and reporting constraints. The power of this evidence is increased by the geographical and social diversity of the participants, providing impetus for radical reform of learning. Policy makers require these practical demonstrations of curriculum transformation with computers to inform the community and make political decisions about the content of schooling palatable and feasible (Kozma 2011, p. 27). This is particularly true in the case of disruptive innovation (Cerna 2013, p. 14).

The researchers have been asked if the Year 6 students really understood integral calculus. The response is students generally passed the university test designed to assess this specific learning achievement. A counter-argument is the students had assistance, in the form of the computer software they used when solving the posttest problems. The Calculus for Kids students needed to know, what mathematical tools to use, when to

use them, and how to use them. This required understanding of the concepts within integral calculus and their application. It is clear there are difficulties when thinking about the impact of computers when transforming curriculum, but there is a clear imperative to do so given their pervasive use in professional and business life. As with any technological innovation, its use replaces old skills with new ones. In Calculus for Kids, the skills to operate the Maple software replaced the mechanical memorization of algebraic formula manipulations. The consequence was that students were able to solve real world problems using integral calculus, which is indicative of higher order thinking.

The study only demonstrated accelerated learning achievement with elementary school students. However, analogous processes could be trialed at other educational levels. For instance, 1st year undergraduates might be able to achieve learning outcomes at the Masters’ or even initial PhD candidate level. Year 10 students may be empowered to demonstrate understanding from 1st year degree courses. This would be a significant outcome for transformative uses of computers in education.

Conclusion

There is no doubt that school education suffers from plurality of control and the inertia evident in any large system. Both educational leaders (Oates 2009) and students (Barrance and Elwood 2018) have expressed concerns that innovations and assessment reforms are proceeding with undue haste. Society needs to contemplate the growing disjunction between the pervasive use of digital technology in professional life and the lack of transformative curriculum changes.

This raises significant difficulties for educational researchers, where the “gold standard” of effect size for evaluating innovation impact needs readjustment. Transformational and redefinition uses of computers make it possible to teach new concepts, not currently in the age-designated curriculum for student subjects. The conventional use of “effect size” comes under increasing strain in



such circumstances. Already there are a variety of statistical calculations leading to an effect size, but transformational computer use makes pre/post testing and the use of control groups very difficult. This entry has argued that many such situations can be addressed by using the concept of a curriculum-age scale. It does leave open the question of transformational learning not covered by the operational curriculum for the relevant, or indeed any other, jurisdictional area. That may be for another discussion!

Cross-References

- Computational Thinking
- Computers and Educational Improvement
- Computing Education, Outcomes of
- Methodological Quality of Educational Technology Meta-analyses
- Technologies in Mathematics Education
- Technology Enhanced Learning

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Classroom Use, Blended Learning

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Concepts: Definitions

Blended and hybrid learning are terms that have become increasingly popular since the beginning of the twenty-first century and they are often seen providing for the best of both worlds, incorporating elements of face-to-face and online digital learning.

According to MacDonald (2008), the blend extends beyond the combination of face-to-face and online elements to cover a blend of various technologies, e.g., synchronous and asynchronous, as well as different pedagogical approaches:

The term (blended learning) is commonly associated with the introduction of online media into a course or programme, while at the same time recognising that there is merit in retaining face-to-face contact and other traditional approaches to supporting students. It is also used where asynchronous media such as email, forums, blogs or wikis are deployed in conjunction with synchronous technologies, commonly text or audio. (MacDonald 2008, p. 2)

Beyond the concept of a simple blend, blended learning is perceived as requiring a fundamental redesign that transforms the whole approach to teaching and learning. It is not just a mixture of face-to-face and online components, but a thoughtful fusion of classroom-based and online learning experiences (Garrison and Vaughan 2008). In other words, the classroom and the online environment are fully integrated in a way that extends learning beyond the classroom, creating a continuous learning experience that makes the best uses of both environments – the classroom and the online space.

According to Allen and Seaman (2010), “blended/hybrid” courses are strictly defined as having between 30% and 79% of their content delivered online. Courses with 80% or more delivered online are named “online” while those having up to 30% delivered online are named “web facilitated” courses (Allen and Seaman 2010). This distinction may initially seem too prescriptive; however, it is useful as it highlights the spectrum of forms of course delivery.

The University of Glamorgan has adopted a similar definition of blended learning which is based on a continuum (Jones and Man Sze Lau 2010). This continuum includes the whole range of information and communication technologies (ICT)-enabled learning, from basic ICT usage to complement face-to-face teaching to fully online delivery of units/modules. Jones and Man Sze Lau (2010) underline the importance of pedagogical design in the adoption of technology, making clear that their model does not imply a simple technological add-on to existing modules, but a total redesign of the whole module/unit.

While all learning can be blended, the blend can be between various types of technology,

blending the physical with the virtual (online) environment, but also blending classroom pedagogies with the use of various technologies to enhance students’ learning. The remainder of this entry will focus on blended learning approaches in the classroom.

Classroom Technologies for Blended Learning

Classroom technologies for blended learning add interactivity in the classroom, making the student learning experience more engaging, including lecture capture software, visualizers, interactive whiteboards (IWBs), the use of mobile devices, electronic voting systems (clickers), and other online voting applications.

Separate sections will cover the following classroom technologies:

- Lecture capture technologies
- Visualizers/document cameras
- Interactive whiteboards (IWBs)
- Interactive screens
- Mobile learning – bring your own device (BYOD)
- Electronic voting systems (clickers) and online voting applications
- Augmented reality applications
- Virtual reality applications

Lecture Capture Technologies

“Lecture capture” refers to the process of recording lectures. In the past, the term was used to describe various methods of recording a session including video cameras, or even plain audio recorders. More recently, the term is used to describe software that automates the process of recording and uploading of the session to the relevant module through a virtual learning environment (VLE) or course management system (CMS).

Lecture capture software can be used for either manual and/or scheduled recordings; scheduled recordings have some implications regarding administrative workload and system integration. In many cases, only a microphone is used to record audio alongside the slides, or other desktop

applications are projected on the screen. Optionally, video input can be captured using either a mounted camera in lecture theatres (if available) or, alternatively, a plug-and-play web camera can be used with the software.

Lecture capture is used for a range of educational purposes, such as aiding students' revision, as an assistive technology, to support international students whose English is not their first language, and to improve the student experience in general. Regarding the impact of lecture capture on students' learning, while some studies have found a positive impact, findings about actual student performance are contradictory, with some studies establishing a positive impact on student grades while others report little or no impact (Joseph-Richard et al. 2018). Despite this, lecture capture seems to have a direct correlation with student satisfaction and, due to increasingly globalized and marketized tertiary education, its use has become widespread in many universities.

Some concerns have been raised about the impact of lecture capture on student attendance and it is important to emphasize that, as an educational technology, lecture capture is meant to enhance the learning experience by offering access to lectures for revision purposes rather than as a replacement for lecture attendance, which could have a detrimental effect on student attainment (Edwards and Clinton 2018).

Visualizers (Document Cameras)

Visualizers, sometimes referred to as document cameras, are the modern, digital equivalent of the old overhead projector (OHP), offering additional capabilities. A visualizer is used to project an object for the class. This can be a newspaper article, an image, or even a mobile telephone application that the teacher wants to demonstrate to the students. Other uses of the visualizer include writing or drawing on a piece of paper which is projected to the class. Visualizers can digitize anything that can be projected through them in either pictorial or video format and can also capture that projection in a digital format. Additionally, visualizers offer the option to zoom in and out, enlarging any objects that need to be studied in detail.

Interactive Whiteboards

Interactive whiteboards (IWBs) are commonly used in all educational sectors (primary, secondary, further, vocational, and tertiary). As part of a traditional setup, IWBs are connected to the teacher's computer and a projector; however, newer versions have made the projector obsolete, as they can be back-lit. IWBs are used for presentations, demonstrations, making notes, and drawings as one would do using a traditional board, or for projecting videos to the whole class.

IWBs offer a range of additional functionality including a touch screen that allows the teacher/presenter to operate the computer projected to the IWB from the IWB itself, the ability to write and draw on the screen using the IWB markers to annotate and highlight text, add notes and drawings, and then save the work and export it to either portable document format (pdf) or pictorial format. IWBs are equipped with specialist software that allows the user to write and draw tables and add shapes, images, and web links; this work can also be saved and shared. Additionally, IWBs are equipped with educational software and games for various subjects aimed at learners at different levels across primary and secondary education. Students can use the IWB individually and/or in groups to actively engage with various activities that include a range of subject-based exercises, tasks, and learning games (Barber et al. 2008) as well as use the IWB to present their work to their peers (Passey 2016).

All teacher-led and student-led work that takes place on an IWB in the classroom can be saved, exported, and subsequently it can be made available via the school's virtual learning environment (VLE) or course management system (CMS), a practice that can be beneficial to students for revision purposes (Passey 2016). IWBs can support "seamless integration and sequencing of different media," which can enable "greater fluency and pace of ideas and knowledge progression" (Passey 2016, p. 9).

Interactive Screens

Interactive screens come together with a stylus and allow the teacher to draw directly on the screen. These drawings are displayed on the interactive or static whiteboard for the students to see. Interactive screens are useful primarily in large

lecture theatres where, due to the size and height of the whiteboard, it may be impractical for the teacher to use the IWB.

Mobile Learning: Bring Your Own Device (BYOD)

Mobile learning in the classroom refers to students' access to mobile devices for learning purposes, either individually or in groups. The mobile devices are either owned by the institution or the students themselves, with the latter practice known as "bring your own device" (BYOD). The use of mobile devices in the classroom is still a contentious issue, with some arguing that access to mobile devices can assist learning (Cochrane et al. 2014) while others argue that access to mobiles in the classroom can be a distraction (Moss 2012; Ugur and Koc 2015). It is reported that the higher the students' attainment level, the more likely it is that the use of their personal devices is allowed and encouraged; while bring your own device (BYOD) policies have been implemented by some tertiary institutions (Gillies 2016), this practice of allowing personal use is rarely the case across the primary and secondary sectors where access to mobile devices in the classroom is more controlled and monitored by the school.

Mobile learning can make learning ubiquitous. Access to mobile telephones and tablets can offer expanded learning opportunities. Mobile devices are often used solely for content delivery; however, they can also be used in very innovative, interactive and even immersive ways to support creative pedagogies and collaboration. For instance, handheld devices allow students to create their own content in a variety of formats, collaborate online, and share information, becoming part of an online learning community (Cochrane et al. 2014). Some of the affordances of mobile learning when used in conjunction with other technologies are highlighted in the following sections.

Electronic Voting Systems (Clickers) and Online Voting Applications

Electronic voting systems (EVS), or classroom response systems (CRS), are handheld devices that can be used to increase student engagement with their learning. A question is projected on the

interactive whiteboard and the students can select the right answer using the handheld device (clicker). Free text input is also supported by some of these devices. However, the most commonly used question types are multiple-choice and true/false questions. The use of EVS promotes participation by everyone in the class as all students tend to respond to a question, instead of one student responding to a question when this is asked orally. Furthermore, this practice allows the teacher to see whether a question has been understood by the learners based on their responses. EVS systems have been used to facilitate more discursive, active learning approaches, including a peer instruction approach where students vote, then discuss their choice with a peer, and then vote again (Crouch and Mazur 2001).

Similar to the EVS systems, various online voting applications have been developed recently allowing participants to vote using any internet-connected devices, including laptops, tablets, and smartphones. Some of these applications allow for a wide range of questions to be asked and they can also gamify learning by timing the fastest responses, displaying images, graphics, and sounds, and listing the top winners in a series of questions based on the number of correct answers and time spent in answering them.

Augmented Reality (AR)

Augmented reality describes the process of enhancing an otherwise real environment by means of virtual objects. In other words, the augmentation refers to the process of merging the physical and the virtual environment by superimposing digital information in various formats on the physical environment, providing an immediate user interface to an electronically enhanced physical world (Schmalstieg and Hollerer 2016). Another term for AR is "mixed reality," as it allows real and virtual elements to be combined. A mobile device such as a tablet or smartphone with an AR application is used to scan the physical environment and real-world footage is viewed through the camera. Pre-recorded, computer-generated video is then overlaid in such a way that it can appear to have a location in the physical world.

AR can provide an engaging, technologically enriched learning experience to students (Hsiao

et al. 2013; Ibanez et al. 2014). Augmented reality applications can enhance a visit to a museum, for instance, by providing additional information in various formats to any of the exhibited objects or even make a book come to life by complementing it with audio or video.

Findings from a meta-analysis study (Ozdemir et al. 2018) that examined 16 studies to identify the effect of AR applications in the learning process showed that AR applications increased students' academic achievement as AR allowed them to practice what they were learning in an entertaining environment and it provided better understanding, recall, concentration, and interaction, as well as a more attractive learning environment compared with traditional learning environments.

Virtual Reality (VR)

Unlike augmented reality that merges the physical and the virtual environment, virtual reality (VR) is a simulation of a three-dimensional image or environment that can be interacted with in a seemingly real way by a person using special equipment. Virtual reality applications have been used extensively by the entertainment industry; however, they have been increasingly used for educational purposes. Using virtual reality applications, students can go on virtual field trips to museums for instance. Google has developed software that allows "field trips to virtually anywhere" (Google Expeditions 2018). The teacher can see all their students in class and use their own tablet to control their VR devices and start, pause, and stop the expedition. The teacher can also interact with the virtual environment by circling points of interest to focus the students' attention on a particular area that they want to explain. YouTube has created a VR channel which features VR videos allowing to "catch a concert a continent away or take a trip out of this world" (YouTube 360 2018).

Holoportation: The Future?

Holoportation is still considered a futuristic development, yet it might impact education in the near future. When combined with augmented reality displays, it allows participants to see and hear remote participants as if they were present in the

classroom or other physical space, creating the illusion of a natural face-to-face communication. This development may minimize transactional distance to facilitate more synchronous, visual, and human options (Themeli and Bougia 2016), blurring the boundaries of distance and face-to-face education.

Cross-References

- [Augmented Reality and Its Use in Education](#)
- [Blended Learning](#)
- [BYOD in the Classroom, Opportunities, Issues, and Policies](#)
- [Digital Media Boards in Primary Schools, Use of](#)
- [Formats of Virtual Learning](#)

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Clicker Interventions, Promoting Student Activity and Feedback at University Lectures

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Synonyms

Audience response systems; Digital assessment for learning; Digital formative assessment; Response technology; Student response system

Clicker Interventions: Promoting Student Activity and Feedback at University Lectures

“(..) Context is not always everything, but it colors everything” (Pajares 2005, p. 342), and in academia, the frames and contexts for teaching activities set much of the premise for how we carry out our teaching activities. What is realistic to do in small student groups can be completely unrealistic to do in large student classes. Therefore, Cleveland (2002) and Denker (2013) distinguish among “small” classrooms (30 students or fewer), “medium” classrooms (40 to 100 students), “large” classrooms (100 to 150 students), and “mega” classrooms (200 students or more). In higher education, medium or large lectures often involve less dialogue and communication between students and teachers, and several studies have found that traditional lecturing in such lectures is ineffective in promoting student learning (Deslauriers et al. 2011). Student response systems (SRSs, or “clickers”) are digital tools that can be used to increase student activity in such large lecture settings. This entry will examine how this educational technology influences “how teachers teach and students learn” in higher education today.

Lecturing is the most traditional form of teaching at universities and is still widely used, both in the everyday teaching of university students and on big occasions, when distinguished professors are invited to give guest lectures. There is an interest in oral presentation even outside the university walls, as illustrated by the popularity of TED talks, personal narratives, public lectures, and even stand-up comedy. In recent years, however, there has been increasing criticism of lectures in higher education as an outdated and ineffective method of teaching. This criticism is rooted in the increasing emphasis on student activity and student learning in education, together with an increase in students who are used to being actively included in instruction. Empirical studies support this criticism by showing that student activity and feedback promote student learning (Black and Wiliam 1998; Evans 2013; Hattie and Timperley 2007; Prince 2004) and that students struggle to maintain their attention during

lectures (Risko et al. 2012). Lecturing has also been found to be generally less effective than student-active ways of teaching in enhancing student achievement (Deslauriers et al. 2011; Hake 1998; Knight and Wood 2005; Yoder and Hochevar 2005).

Since campus-based lectures have traditionally offered little room for student activity beyond listening to the teacher talking, lecturing seems to conflict with the idea of good teaching. The primary barrier to involving students as active participants in university lectures is often the number of students present in the auditorium, which affects both the potential amount of time dedicated to each student and the students' willingness to participate due to fears of speaking in public. In these contexts, SRSs can be used to help all students present participate actively, regardless of the group size.

SRSs are digital tools that allow students to individually answer multiple-choice questions using a wireless remote control called a "clicker." The distribution of student answers can be projected on a large screen for the teacher and students to see. The student answers can also be stored for later use. Studies have found that this technology can be used to increase student activity and engagement (Boscardin and Penuel 2012; Kay and LeSage 2009; Keough 2012; Krumsvik and Ludvigsen 2012; Lantz 2010). Interventions using this technology (henceforth called "clicker interventions") can also increase student attention (Blood 2012; Cain et al. 2009; Rush et al. 2010; Sun 2014), have a positive effect on student learning (see Chien et al. 2016 for a review), and be a useful tool for providing both students and teacher feedback on the students' understanding (Egelandstad and Krumsvik 2017a, b, Forthcoming; Krumsvik 2012; Krumsvik and Ludvigsen 2012; Ludvigsen and Egelandstad 2016; Ludvigsen et al. 2015).

This entry presents how clicker interventions can be used to promote student activity and feedback at university lectures. We start by giving a historical presentation of the university lecture to highlight the functions of such lectures, the criticisms raised against them, and the challenges they face in the twenty-first century. We then present various perspectives on feedback and

how feedback situations can inform teacher instruction and enhance student learning and self-assessment. Finally, drawing on research on SRS, we present how clicker interventions can be used to promote formative feedback situations in large plenary lectures.

History of the University Lecture

In the Middle Ages, the word "lecture" (rooted in the Latin word *legere*) meant "to read aloud." At this time, a university lecture involved a teacher reading authoritative texts, most often the Bible or another ancient text, aloud to students. The number of written texts was limited. The students' job was to write down the teacher's dictation and reproduce the texts themselves. The function of the lecture was, therefore, as much about cultural preservation as knowledge distribution. For accuracy, the lecturer needed to stick to the script and could be fined for departing from the text at hand (Friesen 2011).

Following the invention of the printing press in the mid-1400s, the mass production of books began to challenge the lecturer as the sole source of information. As books gradually became cheaper and more available, students could engage in studies independent of lectures. This shift is exemplified by a young astronomy student in the fifteenth century asking: "Why should old men be preferred to their juniors now that it is possible for the young by diligent study to acquire the same knowledge" (Eisenstein 1997, p. 66).

Despite this development, the lecture maintained its original form of dictation and note-taking for quite some time. An indication of a gradual shift from pure dictation can be found in the emerging use of glosses. Explanatory notes were written into the margins of the authoritative texts to assist the lecturer in commenting on different passages, and this paved the way for the use of commentary as a way of mediating between original texts and the audience. By the middle of the seventeenth century, the two ways of lecturing – pure dictation and dictation with the use of comments – appeared to be competing for dominance. For instance, in one 1642 lecture plan,

the first half hour of each lecture was devoted to dictation, and the other half was devoted to glosses and commentary (Friesen 2011).

According to Clark (2006, p. 85), “[t]he eighteenth century appears to be the century when the dictation was first stopped.” In response to concerns over the quality of education, some governments went so far as to outlaw dictations (Friesen 2011). However, famous thinkers like Humboldt, Schleiermacher, and Fichte opposed lecturing as reading. Humboldt claimed that dictation was not suitable for engaging students and argued that teachers should create their lectures following rhetorical and didactical rules. Schleiermacher proposed that lectures should enlighten the audience with knowledge they did not previously possess and guide them toward better understandings (Skagen 2000). Thus, these and other contemporary scholars began lecturing without a set text or glossary. As Fichte (as quoted in Friesen 2011, p. 98) argued, the principal concern of a lecture is not “what is printed in books for us to read,” but, rather, “what has stirred and transformed our spirit” (p. 98). This way of thinking about understanding resonates with the hermeneutical tradition, in which text and spoken words are valuable as far as they are interpreted and brought to life as thoughts. From this perspective, a lecture should not be about the authority of books but about the lecturer using his knowledge to affect the audience. The speaker and his own words are, therefore, important. This represents a shift in the history of the lecture from the authority of the text to the authority of the teacher. Teachers as the authors of their own spoken words came to replace the medieval tradition of teachers reading the same authoritative texts (Friesen 2011).

In the twentieth century, projection media came to supplement the use of speech. The overhead projector was first used by the US military during the Second World War and was introduced in its commercial form in the 1960s. Later, this technology was replaced by similar but more advanced tools for digital projection, such as PowerPoint. Despite these changes, however, the lecture maintained its basic structure, though the dramaturgical effects of the lecture were given more attention (Friesen 2011). Goffman (1981)

distinguished among three primary modes of animation of spoken words: aloud reading, memorization, and fresh talk. In fresh talk, the lecturer improvises the text during the lecture. According to Goffman (1981), fresh talk is the ideal lecture style. With the assistance of notes, this method of lecturing is quite common, although, in reality, many lectures employ only the illusion of fresh talk. As suggested by the concept of fresh talk and fresh talk illusions, lecturing can also be considered a public performance that brings ideas and the written word into life. Hence, lecturing can provide an experience of authenticity that is livelier and more entertaining than the reading of a book on the same topic. Unfortunately, it can also be downright dull. How a lecture is perceived is likely to depend on both the performance of the teacher and the interests of the students.

This brief presentation illustrates both continuity and change in the history of the university lecture. So where does the university lecture stand in the twenty-first century?

The University Lecture in the Twenty-First Century

In the 1960s, the main criticism of lectures was rooted in the emerging criticism of authority in society. In this century, however, the focus of the criticism has instead been that lectures are ineffective in promoting student learning (Mazur 2009; Wieman 2007). Interestingly, this development marks a third shift in the history of the lecture: from the authority of the teacher to a focus on student activity and the learning outcome. An illustrative example is Biggs and Tang (2011) three levels of thinking about teaching. A teacher at Level 1 focuses on the differences among students, believing that there are good students and there are poor students. If the students do poorly, they can only blame themselves. A teacher at Level 2 focuses on what the teacher does. If the students do poorly, it is because the teacher has failed to get the message across. Finally, a teacher at Level 3 focuses on what the students do and how well the intended outcomes are achieved. If the students do poorly, it is

because the learning activities of the course are poorly adapted to promote the intended learning outcomes. From the first two perspectives, lecturing is an unproblematic way of teaching. From the third perspective, however, university lectures are problematic because they rely mostly on teacher monologue and are, thus, unfit for facilitating student activities that promote student learning.

This shift in thinking about teaching seems to be rooted in several developments. For one, the conception of how students learn has changed, such that constructivism has replaced the “transmission view” of learning as the dominating paradigm. Hence, learning is no longer understood as information that is transferred from the lecturer to the students but is “conceptualized as a process of active construction wherein learners drew on prior knowledge and experiences—both individual and sociocultural—as they built new understandings” (Cochran-Smith and Villegas 2015, p. 10). Such an understanding of learning embeds demands both for student activity and social interaction and for the teacher to assess her students’ understanding to adapt her teaching to their learning needs.

Second, there has been an increased focus on effective teaching in higher education, “understood as teaching that is oriented to and focused on students and their learning” (Devlin and Samarawickrema 2010). The global shift from an industrial economy to a knowledge economy has put greater emphasis on the importance of higher education for sustainable development and economic growth. This, in turn, has turned attention to the quality of education, particularly with respect to students’ learning outcomes (Cochran-Smith and Villegas 2015; Đonlagić and Kurtić 2016; George 2006). The number of students enrolling in higher education has also increased dramatically worldwide. This development has resulted in larger student groups, often with different cultural and socioeconomic backgrounds, enrolling in universities. Whereas the university was previously an elite institution for high-achieving and highly motivated student, teachers now must deal with more diverse student groups (Biggs and Tang 2011). Thus, lecturing and otherwise leaving students to study on their

own might serve only to replicate social differences. For this reason, the Bologna Process and National Reforms in higher education have put greater emphasis on pedagogical facilitation to even out social differences and reduce the number of students dropping out.

Third, empirical findings show that student activity and feedback situations *do* promote student learning (Black and Wiliam 1998; Evans 2013; Hattie 2009; Hattie and Timperley 2007; Prince 2004) and that student-active teaching *is* usually more effective in promoting student performance than lecturing (Deslauriers et al. 2011; Hake 1998; Hrepic et al. 2007; Knight and Wood 2005; Prince 2004; Yoder and Hochevar 2005). It has also been found that the human attention span and short-term memory are too limited to process and store most of the information contained in a long lecture (Risko et al. 2012).

In light of these developments, one could ask: Should the university lecture be kept in the twenty-first century?

The most obvious argument is that large lectures enable the instruction of many students simultaneously, which is both time- and cost-saving. Another argument presented by Tone Kvernbekk (2011) is that the monologue of the traditional lecture is less exclusive and, therefore, less excluding than dialogical approaches. She also claims that this form of education is less intrusive because the teacher cannot control whether or how the students receive the information provided. These arguments are reasonable but debatable as a defense for the campus-based lecture. The use of digital lectures and instructional designs like the “flipped classroom” offers alternatives to campus lectures that can be more cost-effective and less exclusive and intrusive, since students can, in principle, watch these videos whenever and wherever they want. Furthermore, digital lectures offer more possibilities than campus-based lectures when it comes to combining different modalities.

However, campus-based lectures do possess a potential advantage over pre-made videos with regard to flexibility and interactivity. During a lecture, students can ask questions, voice their ideas to the teacher, discuss with their peers, and reflect on both the subject and their understanding

under the guidance of an expert. The teacher can potentially improvise and make changes in her teaching based on interaction with students. Traditionally, however, student–teacher interaction has been challenging in large lecture halls with many students. Although the teacher can involve some students by posing questions to the audience, many students refrain from answering due to a fear of speaking up in public, and the few who do speak up might not represent the student group as a whole, giving the teacher a biased view of the students’ understanding.

In this context, the use of response systems has the potential to mediate the interaction between the teacher and all students present, providing valuable feedback to both the teacher and the students.

Research and Various Perspectives on Feedback

Research shows that feedback can have a considerable impact on student learning (Black and Wiliam 1998; Evans 2013; Hattie and Timperley 2007; Kluger and DeNisi 1996; Shute 2008). Feedback interventions have been found to be particularly useful when they raise students’ awareness of how to improve in relation to their current level of performance and the learning intentions (Black and Wiliam 1998, 2009; Hattie and Timperley 2007; Nicol and Macfarlane-Dick 2006; Sadler 1989). However, feedback does not always result in student improvement and may sometimes inhibit learning rather than promote it. Variations in the effects of feedback have been related to its content, form, and timing, and studies have indeed found variations based on these factors (Hattie and Timperley 2007; Kluger and DeNisi 1996; Shute 2008). For instance, the use of extrinsic rewards and praise has been found to have a limited effect on student achievement (Hattie and Gan 2011; Hattie and Timperley 2007), and extrinsic rewards can undermine internal motivation (Deci et al. 1999). On the other hand, feedback has been found to be effective when it provides information on correct (versus incorrect) responses, when it builds previous

changes, when the goals are specific and the task complexity is low, and when it is not perceived as threatening the students’ self-esteem (Hattie and Timperley 2007).

Another variation in the effectiveness of feedback is how different students perceive and use feedback (Bloxham and Campbell 2010; Carless et al. 2010; Hattie and Gan 2011; Higgins et al. 2001; Nicol and Macfarlane-Dick 2006; Sadler 2010). The literature offers numerous examples of students failing to make use of the feedback they are given (see Evans 2013; Jonsson 2013 for reviews on the topic.). This discrepancy is commonly referred to as the “feedback gap.” In a review, Jonsson (2013) found that students’ use (or lack thereof) of feedback is related to their perceptions of the information and the opportunity to use it in the near future. He also found that many students use feedback passively to motivate themselves or to indicate progress but lack strategies for employing the feedback actively. Critical feedback also seems to undermine performance and motivation when strategies for improvement are lacking (Ilgen and Davis 2000; Kluger and Van Dijk 2010). In other words, whether feedback situations have the desired effect depends not only on external conditions but also on the students’ internal conditions. Since students have different preconditions (e.g., conceptual understanding and strategies) for interpreting and using feedback, the effectiveness of feedback cannot be explained merely by its content, form, and timing; one must also consider how the feedback is received and used (Boud and Molloy 2013).

Nelson and Schunn (2009) argue that feedback has three major effects: (a) motivational, to influence beliefs and willingness to participate; (b) reinforcement, to reward and punish specific behaviors; and (c) informational, to change performance in a particular direction. Students’ experiences of feedback are likely to consist of a combination of these. It is, therefore, understandable that feedback may both support students’ learning processes and have a negative impact depending on the context, since the way in which students respond to feedback is likely to be influenced by both its emotional impact and the information it provides (Price et al. 2010).

Students differ in the ways they face difficulties and failures, and while some students may choose to respond to feedback by increasing their efforts to improve, others may become demotivated and choose to reduce their efforts or give up (Boekaerts and Corno 2005; Yorke 2003). Hence, feedback also affects and is affected by students' emotions and motivation.

Another difference in how feedback works is related to different actors' understandings of the concept. As noted by Evans (2013), the way in which feedback is conceived depends on "the particular feedback paradigm adopted" (p. 71). Different understandings of feedback lead to various feedback practices: from monologic to dialogic and from teacher-controlled to student-involved. For researchers, different understandings lead to various ways of studying these practices. The fact that practitioners, students, and researchers operate with different and often unarticulated understandings of what feedback *is* and its function highlights the need to clarify how feedback is understood. The most influential sources for conceptualizing feedback in this entry are Hattie and colleagues' (Hattie 2009; Hattie and Gan 2011; Hattie and Timperley 2007) "visible teaching and learning" perspective and the formative assessment perspective as it is presented in the most frequently cited texts in the field (Black and Wiliam 1998, 2009; Nicol and Macfarlane-Dick 2006; Sadler 1989).

Formative Feedback

The visible teaching and learning perspective (Hattie and Gan 2011; Hattie and Timperley 2007) and the formative assessment perspective (Black and Wiliam 1998, 2009; Nicol and Macfarlane-Dick 2006; Sadler 1989) are similar in their emphasis on the importance of raising students' awareness of their learning process. Hattie and Timperley (2007) focus on feedback to the students, while Black and Wiliam (2009) focus on feedback for both the students and the teacher. The purpose of feedback is to make the learning process visible to the students to support their self-monitoring and self-regulation both in the short term, when they are working with

particular tasks, and in the long term, to enhance their abilities as self-regulated learners. In particular, feedback is considered effective when it answers the questions: *Where am I going?* (feed up), *How am I going?* (feed back), and *Where to next?* (feed forward) (Hattie and Timperley 2007).

Both Black and Wiliam (2009) and Hattie and Timperley (2007) regard all situations that promote reflection as situations of formative assessment/feedback. Black and Wiliam (2009) claim that:

Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited. (p. 9)

whereas Hattie and Timperley (2007) define feedback as:

...information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding. A teacher or parent can provide corrective information, a peer can provide an alternative strategy, a book can provide information to clarify ideas, a parent can provide encouragement, and a learner can look up the answer to evaluate the correctness of a response. Feedback thus is a "consequence" of performance. (p. 81)

Both these definitions are quite broad, and their main difference is that Black and Wiliam (2009) focus on "evidence" that can be used by both the students and the teacher, while Hattie and Timperley (2007) focus solely on the student.

Since the definitions seem to apply to every situation that promotes reflection for the students (or teacher), what distinguishes an intentionally driven formative practice from more or less random events? According to Black and Wiliam (2009), "formative assessment is concerned with the creation of, and capitalization upon, 'moments of contingency' in instruction for the regulation of learning processes" (p. 10). In the context of education, therefore, an intended formative practice depends on the teacher facilitating situations that elicit evidence of student understanding.

Thus, the practice of formative assessment/feedback in the lecture hall depends on creating

situations in which the students can engage with the subject and receive feedback on their understanding to make more informed decisions in their studying, as well as on the teacher receiving feedback on the students' understanding in order to make informed decisions about her teaching. When feedback is conceived in this way, it is freed from a "transference" understanding of the concept, in which the teacher "tells" the students something about their performance. Instead, feedback represents the very phenomenon of the experience that arises when we act and suffer the consequences (Dewey 1997). This opens the possibility that feedback situations sometimes occur unintentionally. From such a perspective, it is the situations and the students' experiences of them that become our focus, not a message from "a sender" to "a receiver." In this context, clicker interventions can be conceived as situations in which students need to act, articulate, use their pre-understandings about various topics, and suffer the consequences of their actions, while the teacher needs to act on the feedback from the student answers and plenary discussions, which reflect on their teaching.

In this entry, we use the term "formative feedback" to distinguish between feedback as an intention or something given and feedback that becomes a learning experience. Shute (2008) introduced this term, defining formative feedback "as information communicated to the learner that is intended to modify his or her thinking and behavior for the purpose of improving learning" (p. 154). This definition differentiates between formative feedback aimed at improving learning and summative feedback for certification and control. However, to conceptualize formative feedback as an experience, not as an intention, we propose that formative feedback can be understood as a consequence of our actions; for example, just as putting your understanding into action through a discussion can reveal misunderstandings, running on the ice and breaking your leg can painfully teach you to be more careful next time. This definition also encompasses feedback that immediately enhances the students' understanding of the subject matter, not just feedback that leads to

self-assessment (metacognition). Below, we will use this understanding of feedback to present and discuss research findings on the use of clicker interventions.

Student Response Systems: Affordances and Research

A distinction can be made between SRSs operating with a designated handheld device, a "clicker," with a receiver connected to a computer, and web-based systems in which the students bring their own devices, such as smartphones, tablets, and computers. The benefit of the clicker systems is that they are easy for the students to use and usually yield a response rate close to 100%. These systems also allow the students to be sure of their anonymity when they answer if the devices are handed out at the lecture. The benefit of the web-based systems is that they are usually free to use. Furthermore, the lecturer does not have to distribute any physical devices at the lecture. An obstacle, however, is that some students cannot participate due to connectivity problems or because they do not possess a compatible device.

In large lectures, SRSs are usually employed for formative purposes to ask students subject-related questions during the lecture; however, clickers have also been used for student evaluation and summative assessment. Some of the challenges of using SRSs are that students may forget to bring or lose their remotes (when they are not handed out at the lecture), that the remotes may not function properly, that less experienced teachers may have trouble adjusting their teaching in response to student answers, that classes using SRSs may cover less course content, that creating SRS questions is time-consuming, and that students do not like when SRSs are used to monitor attendance or for summative tests (Kay and LeSage 2009).

Studies have shown that when SRSs are used for formative purposes, the students' attitudes toward the technology are generally positive. Findings also reveal that using clickers leads to increased student attendance and preparation, greater student engagement, and student

appreciation for being able to participate anonymously (Boscardin and Penuel 2012; Kay and LeSage 2009; Keough 2012; Krumsvik and Ludvigsen 2012; Lantz 2010). Studies have also found that clicker interventions increase student attention (Blood 2012; Cain et al. 2009; Rush et al. 2010; Sun 2014), and the majority of studies show that clicker interventions can have a positive effect on student learning (see Chien et al. 2016 for a review).

A common criticism of clicker studies is that they are overly oriented toward technology and lack a theoretical foundation (Beatty and Gerace 2009; Boscardin and Penuel 2012; Fies and Marshall 2006). It is reasonable to say that the theoretical underpinnings for clickers are still in their early stages and need to be developed. Instead of using “grand theories” adopted from other disciplines, it seems important to develop “home ground” theories that build on education, educational technology, and digital artifacts. This implies both theories that can explain the particular phenomenon of such educational technology use, but also analytical frameworks that hold true beyond the local setting to allow broader and more in-depth discussions of research findings outside the context of a particular study.

Although the use of digital tools offers new possibilities for instruction, it is the way in which such tools are used pedagogically – and not their use, per se – that influences students’ learning processes (Clark and Mayer 2011). This illustrates the need to distinguish between the potentials of the technology and the ways technologies can be applied. In the following section, we will present the two most common ways of using clicker interventions before reviewing research on these interventions through the lenses of formative feedback.

Clicker Interventions: The Classic and Peer Instruction Approaches

The two most common ways of conducting clicker interventions for formative purposes are what Nielsen et al. (2016) refer to as the “classic” approach and the “peer instruction” approach. The “peer instruction” approach is based on the work of Mazur (1997). Students are asked a multiple-choice question that they answer individually

before discussing their answer with the students seated next to them and re-answering the same question. In the “classic” approach, students discuss with their peers before answering individually. In both approaches, the teacher usually follows up on the student answers with a plenary discussion. Some studies have used similar interventions without peer discussions (Campbell and Mayer 2009; Mayer et al. 2009; Shapiro and Gordon 2012, 2013). After students have answered the clicker questions, a histogram of the students’ answers is usually projected on a large screen, and the teacher follows up by asking the students to explain their reasonings and providing them with her own explanations.

Clicker Interventions Through the Lenses of Formative Feedback

From clicker interventions (including the clicker questions, peer discussions, and follow-up phase), students may experience two kinds of feedback: (1) feedback supporting their self-assessment (metacognition) by raising their awareness of their understanding and (2) feedback enhancing their understanding of the subject matter. The first kind of feedback relates to studies showing that clicker interventions do raise students’ awareness of their understanding (Egelandsdal and Krumsvik 2017a). The second kind of feedback relates to studies showing that clicker interventions can also have an immediate effect on student achievement (Chien et al. 2016; Egelandsdal and Krumsvik 2017b). Clicker interventions can also provide the teacher with (3) feedback on the students’ understanding. In the next subchapters, we will use these potential “feedback outcomes” to structure and present research findings related to formative feedback from clicker interventions.

Feedback Supporting Students’ Self-Assessment

Feedback supporting the students’ self-assessment entails situations that raise the students’ awareness of their understanding. Such situations can arise from being asked a question, discussing the question with peers, and/or listening to the teacher or

other students talk during the follow-up phase. This kind of awareness can be broken down into three strands of information: *feed up*, *feed back*, and *feed forward*. Feed up denotes understanding what is essential to learn in the course (important topics, concepts, etc.). Feed back means understanding how well the students have understood the subject matter. Feed forward means understanding what the students need to focus on to improve (Black and Wiliam 2009; Hattie and Timperley 2007).

Studies have shown that creating situations that raise students' awareness of their understanding can improve student performance and help students self-regulate (Hattie and Timperley 2007), particularly when it comes to low-achieving students (Black and Wiliam 1998). As illustrated by the Dunning-Kruger effect, low competence can lead people to overestimate their abilities (Kruger and Dunning 1999), and low-achieving students tend to overestimate their understanding of subject matter (Isaacson and Fujita 2006). If students are not challenged to articulate their understanding, their self-assessment depends on seeking out and creating feedback situations on their own (Clark 2012). Since students differ in their approaches to studying, the ways in which they adapt their focus and effort will also differ (Biggs and Tang 2011; Nicol and Macfarlane-Dick 2006).

Krumsvik and Ludvigsen (2012) and Ludvigsen et al. (2015) found that clicker interventions made students more aware of their understanding (feed back). Egelandstad and Krumsvik (2017a) confirmed this finding and also found that most students experienced that, compared to lectures without clickers, the clicker interventions provided them with more information about what was important to learn in the subject (feed up), revealed misunderstandings (feed back), and showed them what they needed to study further (feed forward).

Ludvigsen et al. (2015) also found that students employed the feedback from the interventions in various ways in their coursework. Based on six interviews, they found that students used their experiences from the clicker interventions to identify difficult topics for further study, to discuss tricky concepts with one another, and to

adjust the focus of their reading. One student also claimed that the clicker interventions had transformed the way she studied, leading her to use questioning as method for self-assessing her understanding in her coursework. Egelandstad and Krumsvik (Forthcoming) also investigated whether and how students used the feedback from clicker interventions by using student logs. They found that, of their 23 participants, half (11) reported using the feedback from the interventions in their coursework, while the other half did not. Some of the students used the clicker questions as a reference point for their understanding of the course material, either by employing the clicker questions while studying or adapting their focus in light of how they assessed their understanding of the different topics. Others used the questions to engage in discussions. These students emphasized that discussing the questions afterward made them more aware of the different concepts. These approaches show that some of the students used the interventions to clarify and organize new knowledge and to self-assess their understanding. This may be particularly useful for first-year students confronted with a wide variety of concepts and theories for the first time (Nicol 2009).

Obviously, teachers cannot give students individual feedback during lectures. In such contexts, through clicker questions, peer discussions, and teacher follow-up, clicker interventions provide students with several opportunities to adjust their focus when assessing their understanding of different topics. However, reaping these benefits requires students to be able to both understand and purposefully use the information they receive. Some students may become overconfident if they answer a question correctly or be unable to use the information from the interventions purposefully. For example, in Egelandstad and Krumsvik (Forthcoming) study, only half of the students reported using the feedback in their coursework, even though most students experienced that the interventions raised their awareness of their understanding of the material and what they should focus on further. This illustrates that the teacher might need to guide students on how to consider and use information from the

interventions in their coursework and how the interventions align with course activities and learning intentions.

Feedback Enhancing Students' Understanding of the Subject Matter

The second kind of feedback concerns situations that immediately increase students' understanding of the content. Assuming that questions about key topics, reflection on these topics, discussions with peers, and listening to the perspectives of others (both students and teachers) can contribute to developing a student's content understanding, this kind of feedback can be measured by changes in student performance before and after clicker interventions.

Previous studies have found that the use of clicker questions can increase students' retention (Campbell and Mayer 2009) and that lectures using clicker questions improved students' exam performance by one-third of a grade compared to lectures without clickers and lectures without questions (Mayer et al. 2009). These findings can be related to the testing effect (Roediger and Karpicke 2006), which has shown that the use of questioning can, in itself, improve student retention. Shapiro and Gordon (2012) found that the use of clicker questions in a psychology class improved performance on delayed exam questions by 10% to 13% and concluded, based on their controlled experiment and survey, that interventions invoked the "testing effect." In another study, Shapiro and Gordon (2013) found that the use of clicker questions also promoted significantly higher performance on test questions than repetition of the same material.

With respect to the peer discussions, several studies have found that the number of students answering correctly increases when the same clicker question is re-answered after the discussion (Crouch and Mazur 2001; Mazur 1997; Rao and DiCarlo 2000; Smith et al. 2012; Smith et al. 2009; Vickrey et al. 2015). The average improvement varies between 8% and 30%. Smith et al. (2009) found that the number of students answering correctly also increases when the students are asked a new (isomorphic) question after the discussion requiring approximately the same level of

understanding as the first question, but posed as a new case. The average improvement on these isomorphic questions was 21%. In a similar study, using isomorphic questions, Egeland and Krumsvik (2017b) found an average improvement of 12% on the second question after the discussion, as well as a Cohen's *d* effect size of 0.66. This is 65% above the average effect of interventions aimed to increase student performance, which is 0.4 (Hattie 2009). These studies show not only that the students improved on the initial question they discussed but also that the knowledge they gained transferred to a new case.

Some studies have also found that the combination of peer discussions and teacher follow-up can enhance student performance even more (Smith et al. 2011; Zingaro and Porter 2014).

Feedback to the Teacher

There is a considerable difference between teachers' and students' understandings of various lecture topics (Hrepić et al. 2007). This makes it hard for teachers to assess how students receive the material presented. This is a challenge for the teacher because the students' pre-understanding has a significant impact on how a lecture is experienced (Schwartz and Bransford 1998). One of the benefits of using clickers is that a teacher can quickly collect answers from all students present. Although studies have shown that clicker results can sometimes misrepresent some students' understanding (James and Willoughby 2011; Knight et al. 2015; Wood et al. 2014), the interventions do provide the teacher with a general idea of how well the students have understood the material (Anderson et al. 2011; D'Inverno et al. 2003; Kolikant et al. 2010). This feedback can be used synchronously to address the students' understanding and misconceptions in the follow-up phase (Kolikant et al. 2010) and asynchronously to adapt future lectures and the amount of time spent on various topics to the students' needs and current levels of understanding (Anderson et al. 2011; D'Inverno et al. 2003).

The teacher must, however, be aware that there are several nuances not captured by clicker answers (James and Willoughby 2011). Since clicker questions are multiple-choice, both the

questions and the answers need to be constructed by the teacher; thus, they might not accurately represent students' own questions and ideas. It is, therefore, crucial for the teacher to follow up on the students' answers at the end of the interventions to ask them to explain their reasoning or to use a digital tool (e.g., Flinga) to enable the students to write their comments, answers, and questions freely.

Negative remarks from teachers concerning clicker interventions are usually related to a loss of lecturing time (Egelandsdal and Krumsvik *Forthcoming*). This illustrates the major trade-off when using clicker interventions, namely, that there will be less time for lecturing. If the teachers experience, however, that they are "teaching more by lecturing less" (Knight and Wood 2005), this trade-off might be well worth it. As illustrated in many studies, the amount of material covered does not equal the amount of material learned (Deslauriers et al. 2011; Hake 1998; Hrepic et al. 2007; Jennifer K. Knight and Wood 2005; Yoder and Hochevar 2005). As noted by one of the teachers in Egelandsdal and Krumsvik (*Forthcoming*) study, it is better to focus on a few important points than to provide students with a great deal of information that they do not retain. Since humans have limited short-term memory and attention spans when it comes to retaining information from lectures (Risko et al. 2012) and clicker interventions increase student attention (Blood 2012; Cain et al. 2009; Rush et al. 2010; Sun 2014), this is a valid point in itself. Studies have also found that brief activities help students remember more content (Prince 2004), that the use of clicker questions enhances student retention (Campbell and Mayer 2009; Mayer et al. 2009; Shapiro and Gordon 2012, 2013), and that students are likely to understand more of the content if it is simple, explicitly stated, and reiterated multiple times (Hrepic et al. 2007). Hence, reducing the amount of material covered, slowing down the tempo, and using questions and peer discussions might be acceptable from a "student learning" point of view.

The ways in which teachers use SRSs depend on the possibilities they identify, both with respect to the affordances of the technology and the

pedagogical opportunities to facilitate purposeful activities. How these activities play out might also be affected by unintended events and consequences (Kirschner et al. 2004). Studies have found that the perceived advantages of clicker interventions increase when teachers become more experienced with using them (Draper and Brown 2004; Kolikant et al. 2010). In this respect, it is important for teachers to be aware that becoming familiar with the technology, creating appropriate questions, and learning how to adjust their teaching based on information from clicker interventions are likely to be a process of development (Boscardin and Penuel 2012).

Conclusion and Suggestions for Practice

In this entry, we have seen that clicker interventions can be used to promote formative feedback and student activity in university lectures. Clicker interventions can be used to engage students in peer discussions and gather answers from all students present, and they also serve as a catalyst for plenary discussions. A benefit of clicker interventions is that they allow the teacher to collect answers from the whole student group instantly, usually yielding a response rate close to 100%. They also work well regardless of group size. Clicker interventions can inform teachers and students about the students' current understanding and can be used to adjust studying and teaching. As we have seen, clicker interventions can also have a positive impact on student learning, motivation, attention, and engagement.

A limitation is that both the questions and answers in clicker interventions need to be pre-constructed by the teacher, since they are multiple-choice. It is particularly important that the teacher pay attention to the purpose of the lecture when constructing the questions. A recent study found that the use of solely factual questions can improve student retention, but simultaneously impede conceptual understanding because they can orient students too heavily toward facts (Shapiro et al. 2017). Even in a multiple-choice system, it is still possible to construct questions to which the answers are not merely "right" or

“wrong” by, for instance, using questions for which the alternative answers represent different perspectives on a topic. It is also possible to construct questions that require a deeper understanding, such as case questions that the students must use their understanding of the subject matter to solve. The clicker questions can also be used in combination with modalities other than text and speech. For example, in studies by Ludvigsen et al. (2015) and Egelandstad and Krumsvik (2017a), the lecturer used a combination of clicker questions and video cases. In these cases, the students needed to employ their understanding of the subject matter to interpret and solve the cases presented to them. Professor Rune J. Krumsvik, who has used clickers systematically in large lectures for psychology students since 2008, states that “[t]he combination of such educational technology, peer discussion, authentic video cases from the practice field and feedback as theoretical underpinning, have increased the interactivity and the student engagement, and changed the teachers’ and students’ roles.”

To explore students’ own ideas beyond plenary discussions, it is also possible to collect answers to open-ended questions or allow students to submit their own questions before the lecture for use in the planning of clicker interventions. Another option is to combine the use of clicker interventions with a qualitative response system, such as Flinga. These systems allow students to write text-based answers on a shared digital wall, thereby allowing students to submit explanations for their clicker answers.

Although the kind of questions used is important and different kinds of questions serve different purposes, another essential factor in clicker interventions is the level of facilitated interactivity. If response systems are used in combination with peer discussions and the teacher follows up on the student answers and uses them purposefully to make changes in her lecture, the change from a traditional lecture will be more extensive than if a teacher merely poses a few questions and then moves on with the monologue. The quality of the interventions also rests upon how well the teacher follows up on the students’ answers. For example, a teacher might simply collect the

student answers and not engage them in a discussion of different perspectives or, alternatively, relate the ideas to one another, compare and contrast them, and relate them to existing ideas discussed in the course. This second approach uses information from clicker interventions to create tension between the ideas of the students and the ideas of the discipline, which can allow the students to draw connections between their everyday views and the ideas of the course and to become more aware of the different perspectives on a topic.

Cross-References

- [Information Technology and Assessment](#)
- [Tablet Use in Higher Education](#)
- [WhatsApp for Electronic Feedback and Assessment](#)

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Collaboration and Social Networking

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Similar terms: challenges for social media users and society, dilemmas of social media influence, public discourses on social media impacts, social media as public good, current status and future direction of social media

Social network as medium is a great tool for collaboration among individuals without geographical and synchronous communication barriers. Tools such as Google drive or Facebook allow users to collaborate with multiple individuals not only without geographical distances but also without necessary synchronicity, i.e., people can edit shared files in a cloud server any time anywhere in the world without disrupting the work flow from anywhere in the world. One of the benefits of working on shared files is the efficiency gained through modularization and granulation (Benkler 2007). Massive size data files can be modularized into small fractions and divided among multiple individuals. This way, the workload can become manageable for an individual. A good example of modularization is provided in Benkler (2007). Activist students at Swarthmore College tackled a massive

amount of email exchanges among the employees of Diebold, a voting machine manufacturer, about the defects in their products, by dividing the work through modularization. The modularization has a powerful impact on data processing by allowing individuals with a clear objective to produce and share the outcomes of their work among themselves or with the public. The recent case of Panama Papers is another example of high-profile social network collaboration. Analyzing the massive amount of documents that eventually became known as Panama Papers (see Harding 2016) was an almost impossible task for an institution, let alone an individual. Also, the work required an unprecedented amount of resources and coordination among experts such as journalists, data scientists, and linguists because the information had to be deciphered by experts and the vast amount of data had to be processed before to be usable. The International Consortium of Investigative Journalists (ICIJ), a multinational alliance of professional journalists, took on the task. ICIJ modularized, granulated, analyzed, and, in the end, reported through the outlets of each journalist's institution. Indeed, this type of work is not just in the areas of the social activism or journalistic work. The advantages of collaboration network are very clear in the current work environment where various social network communication methods such as email, social media, texting, and cloud server elevated the efficiency of communication among the employees of many organizations around the world.

Identities, Trust, and Social Cues

Highly productive collaboration networks share one characteristic that the average social networks often do not have. The identities of the participants are known or recognized among the participating members, at least through pseudonyms. In other words, some level of trust is built in their communication through the known or recognized identities. It is difficult to imagine that the online collaborators would have analyzed and published highly sensitive and controversial information such as the Panama Papers or Diebold email

exchanges without trusting other participants because they had to maintain secure and private in-group communications.

Unfortunately, deception is regular part of social media user experience (Donath 1998). Because social media users often do not know who is on the other side of the screen, it is difficult to build trust with the people they are communicating with. When present, deception can erode trust among the participants of a social media and potentially damage the quality of interactions among individuals online.

In a typical offline situation, social presence of a communicating counterpart is an important element that can foster trust among the participants. As people learn to communicate with others as part of human development, they use the physical presence of others as non-textual clues. The social presence cues provided during face-to-face communication are critical for functional communication exchanges. Demographic information, facial expressions, gestures, voice tones, and many other cues are taken into consideration as people put together their responses in their interaction with others. In text-based online communication, however, many of these cues are absent and only a limited number of cues such as usernames or Internet Protocol (IP) addresses are available (Wood and Smith 2005). This presents a challenge to social media users because the lack of social presence of their communication partners leaves them with only limited cues to use and thus substantially curtails applicability of their offline communication skills.

Still, consciously or unconsciously, social media users use whatever cues they can grasp during online interactions and thus, at times, they can be overly dependent on a small number of cues that they can detect. Easily identifiable among them are writing style, inadvertently disclosed information in texts, IP addresses revealed through site interface, and several others. For instance, social media users can take note of a gender cue in a username (e.g., XenaTheWarrior-Princess) and heavily base their interaction with the owner of the username and the person's posts on the gender cue. Especially if the gender cue is the only social cue that the social media users find

in the posts, they are more likely to use this cue, i.e., female gender, excessively. Furthermore, if the communication exchanges are not satisfactory, they may make disparaging comments about the owner of the username based on sexism. Social context cues theory (Wood and Smith 2005) explains that the heavy dependence on the gender cue can disproportionately influence the way online social network users communicate with one another because no other cues are present and people tend to use any cue that they can find in their communication.

Cooperation Rules and Medium Structure

The (over)use of limited cues that we find during online communication is problematic because the cues, or perceived traits of other users, can introduce social stereotypes into the communication and thus lower the quality of interaction. Combined with the anonymous nature of social interactions online, online social networks can easily become "online cesspools" of our nasty desires (Herbeck 2013). Some researchers proposed that one way to avoid unproductive interactions on online social networks is to enact cooperation rules based on known identities, ongoing relationships, and information about other participants (Kollok 1998). One's history of interactions with other users can offer plenty of information about the user's online behavior and thus having the history available for all participants could make online social network participants more mindful about their manners. On online social networks, however, many of these measures are difficult to implement. For example, users access online social networks from all around the world and each country has its own rules regulating social media participation. In most western countries, there is no mandatory real ID policy or mandatory history archiving (e.g., no history function on Snapchat) for online communication participation because of its legal implications and logistical challenges. Social media sites do have their own legal parameters, but the enforceability is highly limited. For example, Facebook's legal

agreement allows real identity only, but it is almost impossible to enforce real identity during the user sign-up process.

The good news is that the majority of Facebook users, 92%, use their real identities when registering on Facebook (Madden et al. 2013). Maybe, Facebook is special in terms of the number of real identity users because most individual accounts on Facebook, except Facebook “Pages,” utilize existing social network and the site is primarily used for closed network communication where only approved friends in the network can view and interact with one another. Users of such closed-system networks (e.g., Facebook, Instagram, Snapchat, etc.) can enjoy the advantages of interacting with known identities and having informative user interaction history available to them. On the other hand, many other online social networks do not use the closed-network system. Twitter is a good example, although Twitter also has a closed system function that is less utilized by its users. Because Twitter is originally built for the users who want to disperse their ideas by using an open-network system, Twitter posts, a.k.a. Tweets, are accessible to anyone on the network even the users do not have the following or follower relationships (e.g., through hashtags). On top of that, the followers can also take a peek at any public information of a Twitter user.

The openness of different social network services can be classified into three categories: private-micro, semi-private-meso, and public-macro (as defined in Bruns and Moe 2014). The different levels of network openness, in turn, have implications for the exchange of information. Private networks can be used for closed communication with other people who shares similar interest and the examples could include the ICIJ journalists in the Panama Papers scandal and Swarthmore College students in the Diebold case. As illustrated in the cases, people who are geographically dispersed can get together and talk about the topics that they feel passionate about. Because private, micro-level online social networks are more likely to be trusted by their users, the networks can be more effective in facilitating the exchange of ideas and efficient collaborations. Indeed, the advantages of private communication

networks have been well utilized among social media users, sometimes at the peril of the well-being of the society. The private nature of some social networks that allows their users to evade the scrutiny of authorities have facilitated exchanges of ideas that are viewed as socially undesirable or even extreme.

Balkanization and Filter Bubbles

Various types of information have been shared among the members of private social media groups to persuade other members to share some of the group members’ extreme views and further instigate them to take destructive actions against those who do not share the views. The reinforcing nature of in-group communication in private networks allows extreme ideas to take hold and flourish within the community (Sunstein 2009). When the members of a closed private network communicate with one another and keep reinforcing their shared view by exposing themselves only to the information that is consonant with the established view, the extremely one-sided view will become prevalent in in-group online social networks on both ends of the political spectrum, whether left or right. It is difficult to examine private groups’ communication because of the closed nature of their networks. However, even communication in meso- or macro-level public networks such as Twitter show extreme polarization of ideas on politically charged topics (e.g., Smith et al. 2014). The psychological mechanisms of such polarization have been explored by social media researchers as well (e.g., Yun and Park 2011). While we can tout the collaborations among people in a closed network environment to solve problems or advance knowledge and understanding, divided public armed with one-sided extreme ideologies cannot be beneficial for the collective society because a democracy requires compromises among its members who can put public interest over their own ideologies. Unfortunately, it is difficult to deny the divisive role that in-group communication on social media has played in contemporary politics all around the world.

Filtering, a heavily utilized technological innovation, is also contributing to the polarization. Google search engine had revolutionized internet search by prioritizing network centrality such as closeness and eigenvector centrality in ranking search results. In deciding which results should be ranked higher than others, the algorithm tabulated inner edge networks based on the number of hyperlinks from other webpages (Barabasi 2003). Subsequently, the technology evolved into tailoring and personalizing information for individual internet users. Highly personal and relevant information that also matches users' personal taste is now selected, sorted, and prioritized for individuals. Constantly evolving search engine algorithm and business deals that allow companies to share consumer information (e.g., shared beacon information between advertisers and content providers of Facebook, see Schonfeld 2007) is further fine-tuning the technique. Because personalized information is often pushed to the devices used by each individual, people conveniently access pre-selected and superbly tailored information from their device interface with a minimal effort. This personalization is quite convenient and efficient. But, we may be paying the price for the convenience by creating further social and political division among ourselves.

The issue here is not just the static polarization, but the acceleration of the polarization. The filtering and personalization potentially create invisible information bubbles in which individuals are exposed only to the information that fits in their existing political beliefs, i.e., filter bubbles (Pariser 2011). Because contemporary news consumers are increasingly more likely to rely on social media, filter bubbles can pose a serious threat to the cross-pollination of information and perspectives, which is crucial in drawing a consensus among opposing parties in a democratic society. In other words, people may rely less on public information sources such as mainstream newspapers and network television news that are typically less tailored and more broad-based. At the same time, they could consume more of micro-level, precisely tailored information that further pushes already one-sided views of individuals to the edges of the shared social values and norms. In addition, serendipitous exposure to some

information that could lead to a discovery of a new perspective or bridging between opposing views is less likely to happen due to the filter bubbles.

Old and New Hope of Facilitating Engagement: Recommendation/Reputation and Fiero

While there is substantial evidence supporting balkanization and filter bubbles as the outcomes of online collaboration, some researchers have approached online collaboration from quite a different perspective. They have taken a social engineering approach and tried to change the outcomes of online collaboration through new interface design features and/or collaboration mechanisms. One of the engineering innovations is recommendation/reputation systems. Recommendation/reputation systems have been around since the idea of exchanging ideas and goods via online social network began to emerge. In spite of the concerns raised in the early days of the network economy, the online marketplace of ideas and goods, for the most part, have not suffered from the problem of market for lemons where cheap and low-quality goods flood the market and eventually destroy the market. Online marketplaces like Ebay.com and Amazon.com are good examples and their success is often credited to the trust among the participants largely based on the recommendation/reputation system. Without the product reviews or vendor ratings that are now almost ubiquitous on e-commerce websites, it would have been very difficult to build trust between sellers and buyers. It would have been also very slow to initiate, sustain, and diffuse the transactions through the networks. Similarly, quality ratings, including information sharing, of the stories and opinions of others in media outlets have been helping content consumers' decisions such as spending time reading the recommended articles and placing how much trust in the information or perspective in them. The comments posted by many other readers can provide a general sense of the climate of public opinion, rather than reaffirmation of in-group opinions in filter bubbles, and expose news consumers to what

other people think about a give topic. The recommendation/reputation system may be able to counter extreme polarization and even facilitate better collaboration between suppliers, whether information or products, and consumers.

Another group of researchers go even further to engineer collaborations amongst online social network participants through games. McGonigal (2011) suggested that social network games can be beneficial to our mental health, if used and enjoyed properly. She argues that the punitive approaches to video games that focus on negative effects such as violence, social isolation, and mental health need to be revisited. Instead, she maintains, human connections provided through network video games can lead to happiness, because video games can teach us how to achieve goals through collaborations with others by using the gamification method. Because accomplishing a challenging, but achievable, goal through collaborations often provides ultimate euphoric feelings that can be harnessed during game plays, a.k.a. *fiero*, properly gamified network systems can facilitate and motivate productive collaborations among the participants. McGonigal (2011) argues that gamified online networked environment can incentivize individuals through the expectation of experiencing *fiero*. In fact, the two aforementioned examples, Diebold email exchange and Panama Paper cases, contain an element of emotional gratification. They probably experienced *fiero* when they made progress and ultimately completed the assigned modularized and granularized tasks, meeting their collective goals. This collaborative work process to achieve shared goals provides a great sense of shared joy, and it can be a priceless experience, particularly when the completed results made big impact on our global discourses.

Conclusion

Online network collaboration has grown tremendously during recent decades. Although there have been many excellent examples of what network participants can accomplish through the collaboration, its unfortunate drawbacks have also manifested in various forms including but not

limited to extremism, polarization, fear of missing out (FOMO), revenge porn, doxing, and anxiety and depression caused by social comparison. None of these problems are easy to solve because all of them are intrinsically intertwined with many aspects of social and psychological fabrics of our lives. However, it is ill-advised to give up on the positive potentials of online social networks, given the proven benefits and widespread use. Instead, it would be more productive to adopt the social engineering approach and constantly improve the communication networks to bring about positive outcomes to individuals and their society. Proper implementations of reputation/recommendation systems can enable online social network users to distinguish between high- and poor-quality information. By setting good rules, procedures, and goals, we can also help the participants of online collaboration projects experience positive feelings, like *fiero*. Online social network collaboration is still in its early stage and has much potential. More creative ideas, or cocktailing those creative ideas, countering the negative aspects of online collaboration should be developed and distributed to overcome the challenges of the current online social networks.

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Collaborative Knowledge Building

► Collaborative Learning and Patterns of Practice

Collaborative Learning and Patterns of Practice

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Synonyms

Collaborative knowledge building; Group learning; Social constructivism; Team learning

Introduction

Collaborative learning is an educational approach that involves two or more people who learn while working together on a joint task in order to achieve a common goal (e.g., to solve a problem or to design a product) (Dillenbourg 1999a). Collaborative learning builds on the idea that learning is a social activity which takes place when learners interact with their social environment (Vygotsky 1978). It is a research field with a long history that spans multiple disciplines such as sociology, psychology, and learning sciences. Early studies on collaborative learning go back to the 1920s (Allport 1924).

Research in collaborative learning explores the way learning occurs when two or more individuals work together in order to achieve a common goal. In particular, collaborative learning studies:

- The mechanisms that are activated when people communicate and collaborate
- The means to scaffold meaningful interactions between peers that may lead to learning
- The practices that facilitate collaborative learning to improve the learning outcome both from the learners' and the teachers' perspectives.

On a practical level, collaborative learning approaches are commonly adopted and illustrated in classrooms when students are asked to work in groups and deliver a common assignment.

When people collaborate in a social context, meaningful interactions may occur under certain circumstances which will trigger learning mechanisms and eventually lead to learning. However, it cannot be guaranteed that these desired interactions will indeed take place and that they will result in learning. Research has shown that social interaction between students can potentially improve learning and that students benefit more when working with peers (Crook 1994; Fawcett and Garton 2005; Roschelle and Teasley 1995; Slavin 1992; Stahl et al. 2006). To that end, numerous pedagogical methods have been proposed to promote and to scaffold interactions among peers with the premise that these interactions will lead to learning in a social context (Brown et al. 1989; Cobb 1994; Valsiner and Van der Veer 2000).

In recent years, technological advances have led to the use of computers to support collaborative learning either in classroom settings or in online learning contexts. This newly emerged research area is known as computer-supported collaborative learning (CSCL), and it studies how computer-mediated collaboration can scaffold learning (Stahl et al. 2006). On the one hand, using technology to facilitate collaborative activities makes collaboration easier on a practical level. Students have access to common resources, they can share material with the learning community, students' activities can be logged for post-analysis purposes, and, most importantly, students can participate from anywhere and at any time (Crook 1998). On the other hand, the use of technology contributes to improving learning by scaffolding argumentation, fostering co-construction of knowledge, as well as supporting coordination of peers. Additionally, collaboration contributes to shaping the students' behaviors who, in a social context, do not act as individuals but as the members of a team who work together toward a common goal (Scardamalia and Bereiter 1991; Stahl 2005).

In this entry, an overview of the background, the research approaches, and the patterns of practice in the field of collaborative learning are provided. A definition of collaborative learning and an overview of fundamental aspects that shape research and practice in this field are included. Pedagogies and learning theories that are used as foundations of the field alongside goals and objectives of collaborative learning approaches are discussed. Popular patterns of practice, exploring their application in classrooms, and elaborating on the state of the art around those practices in research are outlined. A discussion about important topics, open questions, and future directions are provided in conclusion.

Background

Definition and Fundamental Aspects of Collaborative Learning

Collaborative learning is commonly considered part of the learning sciences. However, it is an

inherently interdisciplinary field that provides a common ground for other research disciplines such as sociology, computer science, and cognitive psychology (Dillenbourg et al. 1996; Hmelo-Silver 2006). Collaborative learning studies the learning mechanisms that come into play when people collaborate to reach a common goal. It also studies the means to support people who share or build common knowledge and eventually how to improve the learning process and its outcomes. However, describing collaborative learning using one definition is challenging due to the complexity of the field (Dillenbourg 1999b) and because it takes place in a wide context (usually wider than a classroom). It involves everyday practices of people who interact within a social arena in which learning occurs under specific circumstances (Lave and Wenger 1991). Vygotsky discussed the role of the social context with respect to learning through his theoretical approach that identified the zone of proximal development (ZPD). The ZPD can be defined as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky 1978). This definition of the ZPD highlights the importance of collaboration and social interaction when it comes to learning.

Collaboration, as an activity, is described by three dimensions that impact the way we design, implement, and carry out collaborative learning activities as well as how we choose means to facilitate them. These dimensions are:

1. *Time*. Synchronous activities – that is, activities that require synchronous communication between learners – usually unfold over short period of times (e.g., a few hours), and students communicate over voice channels, face-to-face when co-located, or instant messaging. Asynchronous activities – that is, activities that do not require synchronous communication between learners – can take place over longer periods of time, and students usually communicate via emails or written texts.

2. *Location.* Typically, collaboration is perceived as a co-located activity. That is, people who work together are expected to physically share the same space. This is not necessarily the case in collaborative learning since the use of technology can provide means for people to collaborate efficiently that are co-located as well as people that are not. In the case of co-located collaboration – for example, face-to-face meetings – technology can provide resources or assistance to support students to interact or to coordinate. In the case of distant collaboration, technology can additionally provide a virtual, common space for people to interact and communicate and thus bridge the gap created by distance.
3. *Group size.* The size of the group in collaborative contexts (i.e., the number of people who work together) can vary from dyads (pairs) and small teams to classroom size (20–30 students) or larger (social) groups like, for example, massive open online courses (MOOCs) or communities of practice.

Several theoretical and methodological frameworks take these dimensions into account when designing and analyzing learning activities (Dillenbourg 1999b; El Helou 2010; Kirschner and Erkens 2013; Pozzi and Persico 2011). There are also approaches that focus on exploring the impact and significance of the aforementioned dimensions on collaborative learning or study-specific phenomena that can be traced back and attributed to these three dimensions (Antunes et al. 2012; Reimann 2009).

Early research in collaborative learning focused on the group level: the interactions between group members, the means (technological or others) that facilitate collaboration, and the effectiveness of these means on collaborative practice. Later on, the research field expanded to include work from closely related fields such as informal learning, game-based learning, educational data mining, and teacher education.

Pedagogies and Learning Theories

In principle, collaborative learning can be considered a constructivist approach that focuses on

the interaction between people (Suthers 2012). As such, it builds on the principles of *constructivism* and *social constructivism*.

Constructivism (Doise et al. 1984; Piaget 1928) emphasizes the way humans develop in relation to their experiences. Similarly, social constructivism (Vygotsky 1980) focuses on how humans learn by interacting with others in a social context. Social interactions can expose people to divergent views and require them to familiarize themselves with new ideas and experiences. In a social arena, humans are expected to be able to elaborate on their own views and perceptions and to externalize knowledge. To enable these interactions and potentially turn them into learning experiences, learners have to establish a common ground which allows them to exchange information and share and build knowledge. In this sense, learning is not just the end goal (or the outcome of a collaborative activity), but it describes the whole process of working with others in a social context and toward a common goal.

The increasing popularity of the field that came along with technological advances in computer science has led to the adaptation of constructivist pedagogical approaches in order to address the specific needs of collaborative learning. Examples of popular theoretical trends in collaborative learning include the theories of *collaborative knowledge building* (Scardamalia and Bereiter 1991), *group cognition* (Stahl 2005), *knowledge-creating organizations* (Nonaka and Takeuchi 1995), and *construction of shared meaning* (Bell et al. 2002).

Research Methodologies

Research methodologies in collaborative learning can generally be classified as *quantitative* or *qualitative*. However, in recent years, there has been an effort to move to mixed methods approaches that involve triangulation between different methodologies.

Quantitative approaches aim to examine the relationship (if any) between factors, to assess the impact of independent variables on dependent variables, and to detect causal relationships. In collaborative learning, a typical dependent variable is the learning outcome, as assessed by

pre- and post-knowledge tests or with respect to the successful outcome of a learning activity. Quantitative approaches are typically *systemic*, in the sense that they involve the use of computational models to model the relationship between quantifiable variables or features and their effect on the collaborative learning process (Greeno and Engeström 2006). Quantitative methodologies include descriptive research, explanatory methods, and experimentation (Johnson 2001).

Qualitative approaches are usually *descriptive* and/or *dialogic*. Such approaches involve field observations of processes or phenomena and their unfolding over time in a specific context, and they focus on the analysis of verbal (or written) interaction between peers to understand the ways people work together (Valsiner and Van der Veer 2000). Qualitative methods used in collaborative learning research typically derive from ethnology, ethnomethodology, discourse analysis, and grounded theory (Lipponen 2002).

Goals and Objectives

The main objective of collaborative learning is to improve the learning outcomes. This objective can be broken down into subgoals that may contribute to improve students' performance, such as to improve the quality of collaboration, to scaffold students' motivation, and to foster creativity.

Thus, research in the field of collaborative learning extends toward several subfields (Lehtinen et al. 1999; Lipponen 2002). It can, however, be grouped into two main categories:

1. Studying *new pedagogical methods* and practices that aim to improve learning
2. Exploring, mapping, and understanding the underlying *collaborative mechanisms* and the factors that affect the outcome of a collaborative activity

The aforementioned categories are neither mutually exclusive nor independent. On the contrary, research usually intertwines both categories. Furthermore, it is important to ensure the effective integration of technological affordances and pedagogical interventions into the learning

design. Therefore, there is a great need for analytical and evaluative approaches in order to inform research and practice. However, analytical and evaluative approaches as well as research regarding learning design are beyond the scope of this entry.

Research Practices in Collaborative Learning

Collaborative learning includes a wide variety of learning activities that range from collaborative problem-solving, argumentation, and project-based activities to game-based or online learning. In this section, an overview of collaborative practices that aim to scaffold learning in a classroom setting is provided. In particular, work practices that stem from the following collaborative learning approaches are presented:

- Collaborative learning over shared artifacts and representations
- Project-based learning
- Game-based learning
- Collaborative learning scripts

These work practices are not necessarily collaborative, in the sense that they can also facilitate individual learning. However, in this entry, these practices are explored as collaborative approaches. Furthermore, these approaches are not necessarily exclusive, but they can be combined to accommodate different learning contexts and goals. For example, it is an established practice to combine collaborative scripts with the co-construction and use of shared representations in order to teach argumentation (Scheuer et al. 2014).

In this section, practices that are usually applied in classrooms have been included. Other popular approaches, such as online communities and MOOCs, are not discussed here. Nonetheless, the reader should keep in mind that the purpose of this entry is to inform about common collaborative practices and recent advances. It is not an exhaustive overview of all existing literature on collaborative learning practices.

Collaborative Learning Over Shared Artifacts and Representations

A *learning artifact* can be any object created by students during a learning activity that can provide “*evidence*” of the learning process (Kafai and Resnick 1996). The collaborative construction of artifacts is a typical activity that can promote learning, elicit reflection, and facilitate communication between peers. In this case, the learning artifact is the outcome of a collaborative process, and as such it reflects the quality of collaboration as well as the potential learning gains of the collaborators (Hoppe 2009). Collaboration over shared artifacts can facilitate collaborative knowledge building by promoting the transition from tacit knowledge (i.e., internalized knowledge that is difficult to communicate to peers verbally or in written form) to explicit knowledge (i.e., formal and concrete knowledge that the learner can communicate to peers) through externalization but also to support reflection by transforming explicit to tacit knowledge through internalization (Nonaka and Takeuchi 1995).

Examples of learning artifacts commonly used in classroom settings are diagrammatic representations – such as algorithmic flowcharts, concept maps, and argumentation diagrams – but also co-written reports, bricolages, or even collaborative portfolios that represent the work of a student group over time. We will explore examples of learning artifacts through a range of research studies in the remaining paragraphs in this section.

Suthers (2005) and Suthers and Hundhausen (2003) studied the use of collaboratively created artifacts, such as graphical representations of hypothesis and relations. They found indications that the use of shared graphical representations can positively influence collaborative learning by enabling communication and stimulating discussion and co-construction of knowledge. Analysis of collaborative learning activities showed that students interact with and through the artifact in a similar way as they would during a discussion. This interaction over a shared artifact enables argumentation and supports participants in reaching an agreement. It was also suggested that the criteria for supporting

participants’ grounding and knowledge co-construction were present in such a setting (Suthers 2005).

Concept maps (i.e., diagrammatic representations that map the relationships between concepts) have been widely used in collaborative learning. Research has shown that the use of concept maps as a collaborative tool promotes the externalization of knowledge (Hoppe and Gassner 2002) and fosters critical thinking and active learning (Daley et al. 2016; Kinchin et al. 2008). Manske and Hoppe (2016) explored the use of concept maps on a meta-level, to inform students and teachers about the progress of collaborative knowledge construction and to scaffold reflection. To that end, they built structured visual representations of semantic concepts based on a model of (shared) student knowledge. The authors experimentally demonstrated how visual representations of collaborative knowledge building can support learners and teach them epistemic fluency.

Collaborative construction of argument diagrams has been shown to be beneficial, in particular, for learning to argue and to co-construct knowledge (Chounta et al. 2017b; Scheuer et al. 2014). Schwarz and De Groot (2007) used graphic tools to promote critical reasoning for argumentation during a history class. Their findings suggest that the co-construction of shared representations benefits students with respect to coherence, decisiveness, and openness.

Voyiatzaki et al. (2004) studied the case of teaching algorithms through peer collaboration over co-construction of diagrammatic representations (graphs) in secondary school classrooms. To facilitate the collaborative building of graphs, the authors used a computer-based environment adapted for the needs of 15-year-old students with minimum computer-related experience. According to the authors, the students were able to adapt to the needs imposed by the setting, they collaborated without difficulties, and the use of technology did not negatively influence the students’ activity. The authors reported no significant learning gains but pointed out important issues that related to resource allocation that should be taken into account when designing collaborative activities for school classrooms.

Kahrimanis et al. (2009, 2011) studied the collaborative creation of algorithmic flowcharts in the classroom for teaching a first-year university course on “Introductions to Algorithms.” Their results indicated that the produced artifacts (i.e., the collaboratively created flowcharts) can capture and reflect the quality of collaboration between peers and they can be used as a post-assessment tool for teachers and researchers.

Collaborative Project-Based Learning

Collaborative project-based learning (PBL) is an educational approach that aims at teaching students by engaging them in pursuing solutions to problems through investigation (Thomas 2000). Learning activities are driven by projects that the students carry out collaboratively in teams. During the process of working together on a common project that reflects the knowledge and skill of the group, the students learn on an individual level through inquiry and self-reflection and on a group level through researching and creating artifacts along with their peers for the purpose of the project.

The outcome of a project is usually a product that addresses the learning objective (Blumenfeld et al. 1991). Typically, the students have to engage in various design, problem-solving, and management tasks while they interact with their peers to successfully complete the assigned project (Thomas 2000). The learning outcome of a project-based learning activity cannot be predetermined. Therefore, students and teachers have to continuously monitor, evaluate, and improve their practice in order to achieve the desirable learning outcome (Barron et al. 1998). Thus, project-based learning is considered an innovative and promising approach for fostering important skills for the twenty-first-century learner, such as critical thinking, collaboration, and creativity (Bell 2010; Chounta et al. 2017a).

Schneider et al. (2002) adopted the idea of project-based learning for web-based educational approaches. In such approaches, the teacher neither instructs nor teaches students actively. The teacher rather encourages students to work and learn independently while facilitating, monitoring, and evaluating the students' practice.

Project-based learning moves away from the traditional teacher-centered model that is usually adopted in education.

Project-based learning is characterized by three principles, according to Schneider et al. (2002): (1) learning that involves students in real-world projects through which they develop and apply skills and knowledge; (2) learning that requires students to draw information from multiple resources in order to solve problems; and (3) learning in which curricular outcomes can be identified up-front but in which the outcomes of the student's learning processes are neither predetermined nor fully predictable. In the next paragraphs, we explore examples of project-based learning approaches.

Han et al. (2015) explored the application of project-based learning in science, technology, engineering, and mathematics (STEM) curricula. They studied how project-based activities affected high school students of different performance levels over a long period of time (3 years). The results of their study showed that low-performing students benefit more from PBL activities than medium and high performers. Low-performing students demonstrated significantly higher growth rates on mathematics scores than high- and middle-performing students over 3 years. In the same study, it was shown that a student's ethnicity and economic status were significant predictors of academic achievement. This implied that students from different backgrounds than the dominating one may have more opportunities to communicate with peers and teachers than they would in a traditional classroom and, thus, they benefit more from PBL activities with respect to performance. This finding has been confirmed by similar studies (Capraro et al. 2010).

Lee et al. (2015) studied collaboration as a twenty-first century skill that can be acquired as a PBL outcome. Furthermore, they attempted to identify how social skills relate to conflicts and how the lack of such skills affects collaboration on individuals and groups. Their findings suggested that task and process conflicts were often transformed into relationship conflicts when students lack social skills. However, when it came to reducing conflicts within groups and to promoting

collaboration, group-level social skills were more influential than individual social skills.

Avouris et al. (2010) reported and discussed their experience when using a mixed approach to teaching an introduction to programming and algorithms during a first-year university course. Their approach combined synchronous collaborative problem-solving along with asynchronous collaboration through project work.

Collaborative Game-Based Learning

Game-based learning (GBL) is an educational approach that capitalizes on *gameplay* in order to achieve predefined learning goals (Shaffer et al. 2005). Contrary to gamification – where gaming features, such as rewards and badges, are used to offer incentives and to motivate students – game-based learning involves the redesign of learning activities so that they will assimilate the fundamental characteristics of games: plots, artificial conflicts, and rules of play (Salen and Zimmerman 2004).

Research argues that educational games can scaffold students' motivation and improve their performance (Burguillo 2010; Papastergiou 2009). Furthermore, game-based learning can offer opportunities for constructive interactions with others that may lead to successful learning episodes. In this context, Voulgari and Komis (2010, 2011) explored the use of massively multiplayer online games (MMOGs) as environments for the emergence of collaborative learning. The authors studied how inherent elements of MMOGs can facilitate collaborative learning and how it is possible to apply collaborative learning principles to the design of MMOGs to promote effective interactions among players. Next, we provide some examples of collaborative game-based learning applications.

Sung and Hwang (2013) used a collaborative game-based learning environment to support students to organize and share knowledge during gameplay. They found that the collaborative gaming environment had a positive effect on students' learning motivation and achievement.

Chen et al. (2015) compared single-player GBL to collaborative GBL. Even though they found significant improvements in learning

outcomes that the authors attribute to GBL, no difference was found between the single-player and the collaborative condition. Nonetheless, the authors suggest that collaborative game-based learning allows students to reconstruct or co-construct knowledge and encourages collective problem-solving and discussion of rich descriptions of science concepts. Furthermore, they pointed out that positive group dynamics – where no conflicts between individuals exist – are necessary for an efficient student practice. Therefore, group formation is a key factor to success in collaborative game-based learning approaches.

Collaborative Learning Scripts

The goal of collaborative learning scripts (or collaboration scripts) is to structure and to scaffold interactions between peers in order to direct and coordinate collaborative practice (Dillenbourg and Jermann 2007). In other words, they script the students' activity to invoke meaningful interactions that lead to learning and avoid harmful interactions that may disrupt fruitful collaboration. Collaboration scripts capitalize on the notion of scaffolding, that is, the support learners receive in order to successfully carry out a task that they would not be able to accomplish without help. This support can refer to *content* (e.g., knowledge about a domain that is required by a learning activity but that a student does not have when starting the activity) or to the *structure* of collaboration (e.g., guidelines about communicating with peers or sharing information) or even to *both* content and structuring.

According to Kollar et al. (2006), collaboration scripts consist of at least five central conceptual components that can be used to formally define them. These components are (1) the *learning objectives* that are pursued with the use of scripts; (2) the *type of activities* that the scripts direct students to engage with; (3) *sequencing*, that is, the planning of activities or tasks that the student will carry out; (4) the *role distribution* among the peers that defines their responsibilities and contribution; and (5) the *type of representation* that will be used to communicate the collaboration script to students.

Dillenbourg and Hong (2008) distinguish between two categories with respect to the script's focus level, that is, the dimension or aspect of collaboration that the script aims to address:

1. *Micro-scripts*, which focus on the communication between peers. Typical examples are scripts used in argumentation learning that aim to teach peers how to facilitate argument construction (Weinberger et al. 2010).
2. *Macro-scripts*, which deal with the organization of the learning activity, such as the description of learning tasks, roles, and groups. Typical examples of macro-scripts are adaptations of Jigsaw, such as Concept Grid, or ArgueGraph (Dillenbourg and Jermann 2007).

The use of scripts has been studied extensively in argumentation and discourse. Stegmann et al. (2007) studied the use of scripts to facilitate argumentative knowledge construction. Their research suggested that scripts could have a positive impact on knowledge construction and knowledge acquisition, on argumentation, as well as on the formal quality of arguments. Weinberger et al. (2005) explored the use of computer-supported collaboration scripts to facilitate argumentative knowledge construction, either by supporting single argument construction or by supporting the construction of argumentation sequences. Their results showed that learners with scripts argued better and acquired more knowledge on argumentation than learners without scripts.

Näykki et al. (2017) studied the use of collaboration scripts from a socio-cognitive monitoring and socio-emotional monitoring perspective. In particular, the authors used collaboration scripts during a first-year course for teacher education students. The objective was to study how socio-cognitive and socio-emotional monitoring processes differentiated during more and less active script discussions. Their results showed that students used the script more in the beginning of the collaborative activity as a means of oneself's orientation to the group and the task.

Wang et al. (2017) explored the use of scripts that could adapt to students' self-regulation skills.

In particular, the authors tested whether the use of scripts that the students could adapt, based on their self-perceived needs, would have an impact on their self-regulation. The results of their work suggested that students who worked with adaptable scripts engaged in more metacognitive activities than those who worked with nonadaptable scripts. Also, the use of adaptable scripts was associated with more monitoring and reflection activities than the use of no scripts.

Collaborative scripts have been criticized for leading students to superficial interactions that do not indicate actual collaboration, when they are designed poorly. It has been argued that collaboration scripts can restrain and restrict collaboration episodes from developing naturally. Over-scripting may lead students to mimic the behavior that the script is anticipating from them – in a way, adopting a “gaming the system” behavior – without in reality engaging in the cognitive and social processes that are necessary for learning (Dillenbourg 2002).

Vogel et al. (2017) conducted a meta-analysis of scripting in order to look closer into the benefits and potential drawbacks of collaboration scripts. Their research showed that although the use of scripts leads to a small positive effect when it comes to domain-specific knowledge, scripts have a large positive effect with respect to collaboration skills.

Important Topics, Open Questions, and Future Directions

In this section, important topics for collaborative learning, open questions, and future research directions are discussed. In particular, the role of technology and the role of the teacher in collaborative learning are elaborated, and future directions and open challenges with respect to research and practice are discussed.

The Role of Technology in Collaborative Learning

The use of computer systems in education is an active research field due to the growth of popularity of computer systems and their use in everyday

life. Since the 1970s and up to this day (2019), intelligent tutoring systems (ITSs) aim to offer targeted and personalized tutoring by tailoring the needs of students and, thus, improving learning outcomes (Corbett et al. 1997). ITS-related research deals with designing activities that adapt to students' needs and prior knowledge. For ITSs, the student is considered an individual unit who learns while one practices with learning material. Because of the lack of social interaction, ITSs were criticized since education and learning are not only about providing knowledge and mastering skills but also about integrating students in a structured society of information and knowledge (Hawkins et al. 1982).

Collaborative learning addresses this criticism since it supports groups of students learning together while collaborating to achieve a common goal. In collaborative learning, technology is used to support collaboration between learners by providing means for communication and coordination, rather than providing sophisticated personalized instruction (Stahl et al. 2006). However, apart from a useful tool, technology in collaborative learning is also crucial for shaping research as well as learning and teaching practices. On the one hand, new learning paradigms such as mobile learning – that is, the educational approach where learning is mediated by using portable devices such as smartphones or tablet computers (Sharples et al. 2009) – have emerged from integrating new technologies in our common practice. On the other hand, teachers adapt the way they teach in order to accommodate changes introduced by technological advances (Jahnke and Kumar 2014).

A typical example for the impact of technology on shaping research in collaborative learning but, most importantly, on learners' practice is the paradigm of massive open online courses (MOOCs). Over the past few years, MOOCs have become very popular. Massachusetts Institute of Technology (MIT) and Harvard University, in a joint statement in January 2017, announced that in 4 years 2.4 million unique users participated in one or more MITx or HarvardX open online

courses, while, on average, 1554 new, unique participants enrolled per day (Source: <http://news.mit.edu/2017/mooc-study-offers-insights-into-online-learner-engagement-behavior-0112>).

It is evident that technology and its impact on learning should not be ignored or downplayed. On the contrary, technology can offer valuable tools that may contribute to improving teaching practices and learning gains when successfully integrated in educational approaches and designs.

The Role of the Teacher in Collaborative Learning

The teacher's role in collaborative learning classrooms is very different from the teacher's role in traditional classrooms (Cohen 1994). In the former case, the teacher, apart from instructing, is responsible for coordinating and supporting the collaborative groups. Furthermore, the kind of support the students need is different in collaborative scenarios from that in traditional classrooms. The students need to communicate effectively and collaborate successfully with their peers. Even though one of the premises of collaborative learning is that students learn by self-reflection and self-regulation which are triggered in collaborative learning settings, interventions by teachers remain necessary when students lack the required skills. Effective collaboration does not happen out of the blue; it requires careful planning of the learning activity and even training the students-peers by using examples of good collaborative practices (Voyiatzaki and Avouris 2014).

A common problem that teachers face in collaborative learning classrooms is to effectively monitor the practice of working groups and to provide support when necessary (Chounta and Avouris 2016; Van Leeuwen et al. 2015). Monitoring collaborative learning activities may refer to:

- Monitoring the *quality of collaboration*, that is, ensuring that the students collaborate in a meaningful and fruitful way without conflicts or miscommunication

- Monitoring the practice of students toward *the learning objective*, that is, ensuring that the learning goal will be achieved by identifying potential misconceptions to prevent failure

Thus, the teacher's goal is to support students when it comes to the collaborative practice but also to the learning objective (Voyiatzaki and Avouris 2014). Furthermore, in the case of collaborative learning activities in a classroom, the unit of analysis alternates between three levels: (1) the individual student, (2) the collaborating group, and (3) the classroom (Stahl et al. 2006; Webb et al. 2006). In order to successfully coordinate the learning activity, the teacher has to assess the students' performances and interactions with respect to these three levels (Voyiatzaki et al. 2008). The workload that teachers have when monitoring and orchestrating collaborative activities becomes even higher when students are not physically present but instead collaborate in virtual groups over the Internet. Therefore, there is a prominent need for tools to support teachers in course orchestration (Chan 2011).

Future Directions

The rapid technological advances have impact on education in general and on collaborative learning in particular. Over the past few years, research on collaborative learning has focused on how to open up *learning communities* and make them easily accessible for everyone (e.g., with MOOCs).

As the name suggests, MOOCs offer open and accessible learning for almost everyone. Every individual with access to a computer and the World Wide Web (WWW) can participate in a wide range of MOOCs depending on her/his interests and learning preferences. MOOCs have also had an impact on research in collaborative learning due to their social aspect. Learning in MOOCs can be supported through social interaction of individual learners with large communities. MOOCs use online discussion forums in order to facilitate communication, information exchange,

and knowledge building among the members of a community. Ongoing research in MOOCs focuses on identifying what kind of user interactions can be characterized as meaningful, thus promoting communication and, consequently, information exchange and knowledge building (Gillani et al. 2014).

Social network analysis and machine learning offer valuable analytical tools to identify the *roles* students adopt when they engage in social interactions, how these roles affect student participation in MOOC forums, and students' performance (Hecking et al. 2017; Wise and Cui 2018). Open questions lie in the way MOOC activities to create meaningful interactions between participants are created. Another challenge is how to provide personalized feedback to students and guide them to adopt knowledge-contributing and knowledge-building behaviors.

In addition to collaborative learning practices, there is a strong need for analysis and evaluation techniques for learning activities. Through analysis and evaluation, it is possible to inform research and practice about their outcomes and plan further improvements. The richness of data collected by applications that facilitate learning activities and the computational approaches that are available for analyzing these data offers a promising approach to improve our understanding of learning. The term *learning analytics* is typically used to refer to the process of data collection and analysis for understanding and assessing learning (Gašević et al. 2015). In collaborative learning, learning analytics are used to gain insights about the underlying learning mechanisms that are activated from social interaction, to assess the learning outcome, but also to provide valuable information about collaboration as well. Open questions are about the way computational models combine data from various sources in order to assess student performance, to predict the outcome of a learning activity, and to prevent student dropout or failure are used. Furthermore, ongoing research explores the potential connection between learning analytics and learning design, that is, how data-driven approaches can inform

course designers and support them in adapting and addressing their specific needs.

A promising trend in collaborative learning practices adapted in classroom settings stems from the *maker movement* and modern DIY (Do it Yourself) communities (Kuznetsov and Paulos 2010). They aim to exploit the benefits from adopting this culture in a formal educational setting. The key point of the maker culture is the creation of artifacts through a creative process in a social arena (Sharples et al. 2014). These artifacts are more than products of an assignment. In essence, they reflect the experience of the maker: what she/he learned, what she/he communicated, and what she/he shared.

The maker movement came together as a “product” of a technologically influenced DIY community (Cavalcanti 2013). Projects in this context are typically technology-driven and combine several disciplines such as crafting and electrical engineering. While DIY projects do not necessarily require group activities, one of the core aspects of the maker philosophy is a maker space. This refers to a real, physical space, which serves as a persistent location for idea and knowledge exchange, planning, communication, and implementation. Modern maker spaces build on the idea of people getting together to exchange their knowledge and their tools. This concept also inhibits social aspects: participants usually share a common space, in some cases they share accommodation, and they participate in social events. Latest trends demonstrate the usefulness of institutions such as coding camps, with some companies establishing such camps as a means for vocational training (Lewin 2014).

Promising new topics for research and practice emerge from the integration of technology in education. The traditional classroom is undergoing change and adaptation in order to accommodate new paradigms that employ technology to scaffold learning. However, technology is not seen as a tool to promote learning on an individual level but rather as a means to support the members of a classroom (i.e., the students as well as the teachers) to establish a “networked society.” In such a society, students work together on artifacts using technology to coordinate and monitor their

activities (thus, scaffolding reflection and self-regulation), and teachers orchestrate learning activities enabling social arrangements and interactions to achieve the desirable learning outcomes.

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Collaborative Practices

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- [Tablet Use in Higher Education](#)

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Community of Practice

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Comparative Analysis of E-Governance and IT Governance

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Introduction

This entry presents a comparative analysis of the e-governance and information technology (IT) governance. The aim is to gain better understanding of the differences and similarities between the two concepts and propose their complementary use.

Many organizations set up computing environments with the main aim of providing improved, effective, and efficient services to their clients, including better collaboration with its partners (Lunardi et al. 2016). This is owing to the popular

believe that IT enables organizations for competitive advantages (Fernando et al. 2016). In some government organizations, the activities of the computing environments are often invoked through e-governance initiatives, with the purpose of providing digitized services to the public at large. E-governance is the process through which many governments make use of IT, to provide services to her citizens (Liu and Liao 2011). The concept of e-governance is also employed by some public organizations, in carrying out activities such as enforcement of public policies, decision-making, and knowledge management (Kumari and Singh 2016).

However, computing environments are not free or immune of challenges, such as risk mitigation, security, reliability, and interoperability management (Dawe 2008). These challenges hinder organizations from operating affectively and achieving their set goals and objectives. Due to various challenges and risks, it was reported that “it is very difficult for the government to keep up with the developments of information and communication technology (ICT) implementations spontaneously” (Kumari and Singh 2016). Some of these challenges ignite many organizations including government’s administrations and agencies to adopt various governance approaches, such as IT governance, in order to improve systems performance, guide technology deployment, manage ICT process, and measure deliverables within their computing environments. Also, some of the challenges could spin from an understanding of the approach, which manifests from the definitions (Lunardi et al. 2016).

The definition and description of the governance approach can be very broad, which bring about vagueness that makes specific goals to be difficult to achieve. For examples, governance is defined as “processes and institutions, both formal and informal, which guide and restrain the collective activities of a group” (Keohane 2002), and Bevir (2012) attempts to clarify the concept by stating that governance include “all processes of governing, whether undertaken by a government, market or network, whether over a family, tribe, formal or informal organisation or territory.” To avoid such circumstance, governance’s definition

is narrowed to the context of this study, which is about rules, processes, and control of an institution or legal entity.

Irrespective of the angle and premise that an individual or organization including government views governance, it is of vital importance to processes and activities within an environment. Thus, many organizations adopt the concept of governance, such as e-governance and IT governance (Ali and Green 2012). However, the deployment of these concepts is a challenge to many organizations including government organizations (Gupta and Bansal 2013). The challenges could be a manifestation of a lack of understanding about the two terms within organization’s computing environments. E-governance and IT governance are broad and ambiguous, which in turn implicates difficulty and inaccurate assessment of IT activities (Cho et al. 2010). Chunyang stated that IT governance is a new challenge that organizations are faced with Chunyang (2010).

The concepts of e-governance and IT governance are concurrently or complementarily employed in computing environments such as the public sector. In common, they share the word governance. The focus of governance is more about whether IT efforts are enabling and supporting organizational strategic goals (Cervone 2017). Other than that, the concepts differ in many ways, such as e-governance entails project and IT governance entails policies (Saxena 2005). Many people from both IT and business (government included) continue to interchangeably or loosely use and sometimes attempt to wrongly apply the concepts in their environments. Primarily, this is attributed to the fact that some employees do not have clear or full understanding of the concepts. Some earlier definitions of the concepts did not help matters either, as they add to the confusion of the misunderstanding or loosely use of the concepts, by being so broad.

Comparative Between E-Governance and IT Governance

The primary aim of the comparative analysis was to provide distinction between the e-governance

and IT governance. The analysis was comparatively carried out from two viewpoints, component and use. The two viewpoints enabled the interrogation of e-governance and IT governance applications, which is critical in defining the comparative of the two terms, respectively.

Component

The component constitute element such as scope, focus, and depth. These elements were selected primarily because they define the concepts and form the basis of organizational requirements and specification for deployment. Therefore, through these elements, differentiation can be made clearer and understood better.

- i. Scope – The scope of the e-governance is primarily on the digitalization of government's processes and activities (Chun et al. 2010). This includes its socioeconomic and geopolitical commitments and orientations (Saxena 2005). IT governance tries to address questions such as what IT capabilities we need to digitize business processes and how will we go about it (Cho et al. 2010). The scope of concepts of e-governance and IT governance are clearly different in scope (Carter and Bélanger 2005). Therefore, they should not be misunderstood for one another.
- ii. Focus – The focuses of the e-governance is on government administration and its activities. IT governance ensures that e-governance is attainable through the development, implementations, and applications of IT standards, policies, and strategies in an effort to deliver IT/business alignment (Al Athmay 2015). Therefore, IT governance focuses on the development of strategies that are needed to monitor and ensure that the right resources technical as well as nontechnical are applied in the selection, development, implementations, utilization, and maintenance of ICT artifacts (Karentzeni and Gouscos 2013).
- iii. Depth – Based on scope and focus, the IT governance is considered to be broader than the e-governance. This consideration is also mainly because the e-governance is a concept that is applied only within government

organizations (Cordella and Bonina 2012; Yudatama et al. 2017), while the IT governance can be applied in a wider spread, from private to government organization, including nongovernment organizations (Shibu and Naik 2017). Also, in scope and depth, the IT governance concept is constantly reviewed to ensure alignment between business and ICT's goals (Cho et al. 2010). Thus, IT governance drives the ICT capabilities that are needed to ensure that an organization become competitive through the ICT resources.

The Use of the Concepts

The actual use of the e-governance and IT governance is one of the main differentiate factors between the concepts. E-governance is used in the public sector, referred to as an ICT innovation management process (Verma et al. 2017), while IT governance is concerned with IT decision-makings, structured processes, policies, responsibilities, and monitoring of ICT in an organization (Serrano et al. 2017). Thus, an understanding of the concepts helps to avoid the confusions that are associated with them, therefore improving the efficiency of their deployment. This includes loosely and interchangeable use of the concepts, which sometimes affects their deployment and objectives. The table below presents the comparison, which is intended to guide their use in the Namibia government, and can be similar to other environments. The comparative analysis was interrogative, by using questioning elements of prefix, which include what, who, how, when, where, and why.

Table 1 is briefly explained to gain better understanding:

- i. What: defines the two terms, e-governance and IT governance, in context to the Namibian public sector.
- ii. Who: defines the initiators and accountable individuals/office, which are not necessarily the implementers of the projects. However, they influence the process in that they are accountable for the success or failure of the projects.
- iii. How: refers to the processes that are undertaken in order to realize the goals of the

Comparative Analysis of E-Governance and IT Governance, Table 1 E-governance and IT governance comparative analysis

	What	Who	How	When	Where	Why
	<i>Material (what it is)</i>	<i>People</i>	<i>Process</i>	<i>Time</i>	<i>Location</i>	<i>Motivation</i>
E-governance	(i) The implementation of ICT to deliver government services to citizens and other stakeholders (ii) To enable and support political processes and activities	Heads of government/ political leaders (ministers)	Defined economic, social, and political objectives translated into ICT specifications and projects	Long-term projects with tangible outcomes achieved within a set time frame. Thereafter it is subjected to maintenance and upgrade	Deployed across all ministry's and governmental agencies	Availability of 24/7 online government services and information to citizen and all stakeholders in order to deliver effective efficient services
IT governance	Structured oriented for controls and risks management of defined ICT projects	Accounting officers of ministries (permanent secretaries) and government agencies (CEO)	By defining policies, principles that are used to manage IT/business alignment through project implementation	A standing IT/business policy established, whereby all ICT projects are subjected to		Ensuring effective and efficient management of IT/business projects services delivery

e-governance and IT governance within an organization.

- iv. When: refers to the time frame within which the e-governance and IT governance initiatives exist and are deployed within an environment.
- v. Where: it refers to the level at which the e-governance and IT governance are deployed within the government environment.
- vi. Why: explains the objectives of developing and implementing e-governance and IT governance initiatives in an organization.

Findings and Discussion

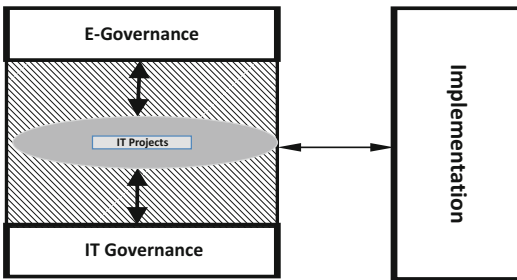
This discussion is based on the comparative analysis carried out above. This discussion is divided into two main sections, commonality and distinction, between the concepts of e-governance and IT governance.

The Commonality

Even though the objective of the entry was not to focus on what is common among the concepts, it helps to gain an understanding of the relationship, as well as the differentiation between the concepts. Also, the commonalities help to gain better perspective on why the concepts are loosely and interchangeably used in many environments.

Both e-governance and IT governance are ICT-related approaches. This means that they are employed for the same objectives, which are to enable, support, and manage processes and activities from the ICT perspectives. The overall objective of governance is to ensure that the ICT projects and environments are aligned to the strategic objectives of an organization (Cho et al. 2010). However, the concepts are deployed differently and at different sizes or scope.

The e-governance and IT governance can be used at either operational or strategic or both levels within an organization. As shown in



Comparative Analysis of E-Governance and IT Governance, Fig. 1 E-governance and IT governance implementation

Fig. 1, both concepts need to be implemented. Project implementation is the medium through which both e-governance and IT governance are realized. Thus, ICT projects can be implemented, using the same resources.

E-Governance

Primarily, the e-governance is deployed with a vision that is divided into three main areas: (i) to avail ease of access of information to the citizens; (ii) to monitor and evaluate public services that are delivered to the citizens; (iii) and to support and enable collaboration between government (including its agencies) and its stakeholders and partners. E-governance thus focuses on socioeconomic activities and political agenda of the government (Potnis 2010). As a result, government agents (ministers and other senior personnel) rely on the e-governance to execute many of their tasks and responsibilities, often through ICT projects.

ICT Projects

Organizational vision is decomposed into goals and objectives that need to be fulfilled through the execution of the e-governance and IT governance, for various activities. The execution is carried out through ICT projects as shown in Fig. 1. IT governance is implemented in public organizations to better serve the implementation of ICT plans, projects, and programs. These ICT plans, projects, and programs can be an e-governance. The ICT projects are derived from the individual mandate and operations of each ministry, which are aimed to automate services. The ICT projects are

defined, developed, and implemented at the ministerial level, in conjunction with the other agencies. On one hand, IT governance guides IT projects. On another hand, IT governance is implemented through IT projects.

IT Governance

The IT governance is used to guide the selection, development, implementation, and application of ICT infrastructures and supporting resources in an organization. However, there are challenges that are associated with the tasks, at all levels, which have become critical due to its misalignment and failures. This can be attributed to weak defined priorities and lack of support from the executives of an organization.

Also, the IT governance is used to ensure that management from both IT and business units do support and implement ICT projects that are aligned to the organization's objectives (Cho et al. 2010). The government personnel of the government administrations often heads the committees that are responsible and accountable for the implementation of IT governance in the organization, in accordance to set standards, policies, and processes. The personnel ensure that all ICT projects are subjected to the IT governance standards.

Implementation

The operationalization of the e-governance and IT governance is done through the implementations of various ICT projects. The implementation consists of technical and nontechnical factors, which include humans (Orozco et al. 2015). These factors require governance in order to avoid or minimize complexities and risks and promote productivity. Under the auspices of the leadership (executive) of a government representative, each ministry develops and implements its own ICT projects. This is intended to guide and ensure that ICT projects undergo due diligence and resource allocation are well managed. The implementation process is conducted through a project plan consisting of a matrix project team, as well as the organization's executive personnel, for accountability. In the National Computing Centre's document of 2005, the implementation of the

IT governance was defined as a project and not as a once-off. The document further describes IT governance as the first key to success.

The commonality between the e-governance and IT governance also manifests from the implementation of ICT projects in an organization. There are two main differences, which include (1) e-governance is more concerned with digitization of business processes through ICT projects and (2) IT governance focuses more on processes, policies, standards, and control measures that are set to guide the selection, deployment, and support of all ICT projects in an organization.

The Distinction

It is imperative that a distinction is drawn between the concepts of e-governance and IT governance. The distinction helps to curb the confusion and the loosely, interchangeably use of the two concepts. From the analysis that was carried out in this study, the distinction is drawn along the lines of the following four factors: categorization, actual use, control, and dependency, as illustrated in Fig. 2.

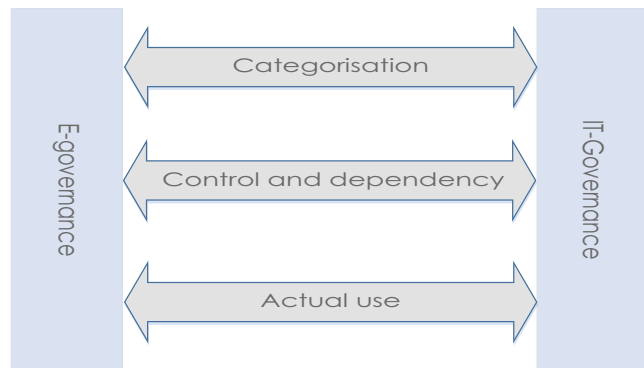
- i. Categorization: e-governance is regarded as the automation or interoperability of systems, while the IT governance is considered a tool or approach that can be used to guide IT efforts across an organization and ensure that strategic goals are achieved (Cho et al. 2010). E-governance's objectives include the digitization of government processes, timely

processing, and sharing of information to citizens and other stakeholders (Shaanika and Iyamu 2015). However to be able to objectively implement the e-governance system, tools and approaches are employed. This is to guide and ensure that the appropriate ICT capabilities in terms of infrastructures, processes, and management skills are selected for successful e-governance operations in an organization.

- ii. Control and dependency: the implementation, use, and maintenance of the e-governance require guidance and support, which can be provided by the IT governance. The absence of effective IT governance causes poor performance of ICT resources, runaway IT projects (e-governance), and possible demise of the IT department in an organization (Ali and Green 2012). Within the government organizations, the selection, development, and implementation of ICT artifacts are carried out in accordance to the definition of the IT governance in an environment. Without IT governance, it is always difficult or near impossible to realize e-governance's objectives. Therefore, in government organizations, it is common to find both e-governance and IT governance in operations.
- iii. Actual use: the e-governance is a system that is specific to government environment, used to deliver services. The application of ICT to improve government services is known as e-governance (Prabhu 2013). Schnoll

Comparative Analysis of E-Governance and IT Governance, Fig. 2

E-governance and IT governance distinction



explains that e-governance encompass local, regional, and central governments and their agencies, as well as other public organizations such as schools and healthcare institutions (Schnoll 2015). Thus e-governance is a concept that can only be applied within the government environments.

However, the IT governance is an approach that can be applied to the entire computing environment of any organization. This implies that IT governance can be applied at both private and public organizations' environments. IT governance such as COBIT ensures that ICT resources are managed by ICT processes to achieve the ICT objectives that meet an organization's business requirements (Rubino and Vitolla 2014).

Conclusion

The similarities observed between e-governance and IT governance are that both ensure the alignment of IT/business objectives, and they are deployed through ICT projects. Specifically, the e-governance focuses on the use of ICT to render online services to its citizens and stakeholders, while IT governance is concerned with the ICT standards and policies to guide the selection, development, and implementation of ICT infrastructure and resources. Both approaches can be implemented in the organization as each has its own distinctive objectives. This distinction is important for politicians and senior government personnel. This is to ensure that they understand their investment on and use of e-governance as a system and IT governance as an approach. That helps with decision-making about the concepts within an environment.

This entry can be useful to academics in educating aspiring specialists in the field of computing, in that it can help to gain better understanding of the differences between the concepts. In addition, the entry can be of vital importance to other interested persons and groups, such as employment agents. The distinction between e-governance and IT

governance as presented in the entry can add valuable input in their classification and categorization of job roles and responsibilities.

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Competency Models in Computing Education

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Synonyms

[Assessment](#); [Learning outcome](#)

Towards the Term Competency

The terms competence and competency have been topics in academic discourse in the educational and vocational context as well as in psychology for several years. Due to their origin, the terms often denote the same construct. Le Deist and Winterton (2005) have explained the different usages of the terms throughout history as well as in different scientific areas. They repeatedly point out the inconsistent usage of both terms but were able to make out different meanings with a partly overlapping understanding. Thus, they come up with three different inspections on both terms, a functional, a behavioral, and a holistic approach. The meaning of the terms covers huge quantities of individual features and traits, such as job-related skills, knowledge, abilities, know-how, performance, etc. A more specific definition was given by Weinert in his works for the OECD, where he defined competences as “the readily available or learnable cognitive abilities and skills which are needed for solving problems as well as the associated motivational, volitional and social capabilities and skills which are in turn necessary for successful and responsible problem solving in variable situations” (Weinert 2001). Klieme et al. (2008) refer to Weinert's definition but exclude the meta-cognitive aspects due to assessment efficiency. They define competencies as “context-specific cognitive dispositions that are acquired by

learning and needed to successfully cope with certain situations or tasks in specific domains.” The important part in all of these definitions is that competencies relate to specific contexts and can be acquired and developed by means of a learning process, although it is not possible to teach competencies per se. They are always the result of an interaction process with the subject someone aims to be competent in.

For further descriptions the term competency will be used. In general, the term denotes a latent construct, which means it is not directly visible but is responsible for certain visible actions. The quality of the interaction of a person with a task is then the assumed degree of competency this person has regarding the subject. For example, a person can be competent with databases. This could encompass being able to normalize a database, to query data from it, or to handle different representational forms such as ER models. The concept of competency must not be confused with the concept of intelligence. Both are assumed underlying psychological traits of persons, yet competencies can be altered by learning and training processes and are context-dependent, while intelligence refers to an extensive construct which is much more difficult to influence via learning processes. The competency of a person becomes manifest when the person is confronted with a problem, where the competency is needed to master the situation. The respective level of competency enables the person to deal with the problem in a more or less adequate manner.

The educational goal is then to focus learning on the development of competencies instead of inert and compartmentalized knowledge of facts. The underlying assumption is that the developed competencies won’t only account for success in school but enable individuals to succeed in later parts in life, such as in vocational or higher education.

All mentioned points have been summarized in great detail in (Klieme et al. 2008) and have been clarified for computer science education in (Hubwieser and Sentance 2018).

Modeling Competency: Competency Models

If learning outcomes in educational processes are targeted toward the development of competencies, it is necessary to clarify which skills and abilities define said competencies and how this should be assessed in order to investigate whether educational interventions were successful. It is thus obvious that in terms of assessment, competencies have to be defined in a pragmatic way. This enables educators to uncover existing problems and to offer individualized support. The gathering of competencies regarding their different areas of performance is usually defined in competency structure models like in the former example of competencies regarding databases. In competency level models, the situational demands to perform a certain task on different ability levels are given to provide possibilities of interpretation of certain task performances. Both are different aspects of the same construct, and as such they complement each other. A third kind of model are competency development models. As the name might suggest, these models deal with the development of an individual competency over time, such as the development of programming competency during the learning process.

General Approaches when Modeling Competencies

An important first step during the process of modeling competencies is the definition of skills and abilities that are necessary to perform tasks in a competent manner. For example, “being competent in the area of object-oriented programming” includes the knowledge about object-oriented concepts, the skills to deal with a formal language like a programming language, as well as the abilities to devise a generalized plan (algorithm) including to review and adapt that plan in case of failure. Of course, each of these areas (often referred to as competency dimensions)

can then still be divided in further subareas (sub-dimensions). A similar approach can be done for every other field where people can be considered competent. Furthermore, on the search for specific competencies, it is not only worth researching the literature for skills and abilities that are needed to solve a certain problem but also for those activities that are often troublesome for a significant proportion of students. Mastering such a troublesome task (such as understanding the concept of polymorphous method calls) can be considered as a gain in competency in this specific area or to the whole competency, which in turn already hints toward specific characteristics of competency levels.

Transforming Competency Models into Psychometric Measurement Models

In order to actually assess theoretically defined competencies, it is necessary to choose an appropriate psychometric measurement model. In the assessment process, test persons are usually confronted with situations that require a certain degree of competency, e.g., a classical pen and paper test situation. The measurement model helps to interpret the results of assessed persons and connects the manifest behavior, usually the test results, with the underlying latent trait, such as the assumed competency. It is important to decide based on theoretical decisions which measurement models should be considered beforehand. If, for example, the assessed construct is assumed to be a latent construct which is distributed on a single continuum, the probabilistic models of item response theory (IRT) are currently state of the art, e.g., the Rasch model. If the test situation assesses skills and abilities from several proposed competency dimensions, researchers can make the choice for multidimensional IRT models (Hartig 2008). Referring back to the example of object-oriented programming competencies, it seems obvious that every constructive programming task usually involves several of the proposed competency dimensions. To program successfully means to handle a formal language, to devise an algorithm, and to

implement it with the help of object-oriented design concepts at the same time. If the probability to solve an item of a test correctly depends on abilities from several dimensions of the proposed competency model, the result can be evaluated under so-called within-item multidimensionality. This would be the case for a typical task like “adding a method to a given class in an object-oriented program.” If all items in a test can be matched to exactly one dimension of the multidimensional competency model (not necessarily the same for all items) and the test results are modeled under the assumption of multidimensional abilities, then this is called between-item multidimensionality. An example would be items which assess the knowledge about object-oriented concepts separated from the knowledge about the syntax of a given programming language. In general, models of within-item multidimensionality have the potential to represent more realistic phenomena, while at the same time they’re more difficult to evaluate.

The choice for models of IRT is also justified by the fact that two aspects are taken into account at the same time: the difficulty of an item and the ability of a person. As a result, they can be mapped onto the same scale, which makes them comparable. With regard to a latent construct, it is possible to order items regarding their difficulty (from “easy” to “hard”) and to order persons regarding their competence (from “unable” to “able”). This requires a different point of view, since comparing the ability of a person with the difficulty of an item is only possible with means of a probabilistic function and has been described in great detail in (Hartig 2008).

Existing Competency Models in Computing Education

A recent example in modeling competencies in the area of informatics modeling and system comprehension was done in the project MoKoM (see Linck et al. 2013). Referring to the former process of the OECD for defining and selecting key competencies, educational documents such as curricula and educational recommendations were

analyzed concerning skills and abilities related to informatics modeling and system comprehension. This resulted in the definition of five different dimensions, system application, system comprehension, system development, dealing with system complexity, and non-cognitive skills, where the latter didn't play any role in the assessment process. Competency in the area of informatics modeling and system comprehension is then always a combination of these assumed independent categories and is determined by how good an individual performs in the single dimensions. The final status of the model is the result of a verification process, where 30 experts in the field of computer science, computer science education, as well as computer science teachers reviewed it. In (Neugebauer et al. 2014) the authors describe the actual measurement process regarding the 4 cognitive dimensions using 292 items on 583 test persons. Evaluating the responses with means of multidimensional item response theory, the results delivered actual evidence that the assumed four dimensions have to be regarded as different ability dimensions. And this in turn has implications for teaching and learning processes as well as for assessment situations.

Kramer et al. (2016) described the derivation process for a competency structure model for object-oriented programming. In analyzing empirically verified competency models from different educational fields like mathematics, science, and music education, a common structure was derived and applied toward the existing scientific knowledge on the topic of OOP. They demonstrated the process of item derivation and could present first results of a test regarding the identification of object-oriented elements in source codes.

Cross-References

- ▶ [Computing Education, Outcomes of](#)
- ▶ [Innate Abilities and Learning in Higher Education](#)
- ▶ [International Reports \(Including OECD\)](#)
- ▶ [WhatsApp for Electronic Feedback and Assessment](#)

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Computational Thinking

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Introduction

At the turn of this century, educators and social scientists began to notice that youth who grew up having intensive, long-term experiences with technology – sometimes called “digital natives”

or “power users of technology” – appeared to think and solve problems differently from those with more limited technology experience. At the same time, computer scientists began to discuss how individuals living, learning, and working in an increasingly technology-driven world would become “advantaged” if they adopted the “ways of thinking” used by computer scientists. They began to describe the ways of thinking that would allow people to take advantage of the affordances of technology for the creative process, for solving previously intractable problems, and for producing new products and services. These trends converge in the concept we now know as “computational thinking.”

Over the past decade, computational thinking has become a global initiative for educational change. Countries around the world are now requiring computational thinking in compulsory education, considering it a needed skill to participate fully in our digital world, in particular, the rapidly changing, highly technical world of work (Bocconi et al. 2016).

This paper shares current definitions of computational thinking and the models/approaches to computational thinking found in today’s schools, discusses the challenges and issues related to computational thinking and its integration into already crowded curricula, and summarizes what we have learned about computational thinking through various strands of current research, illustrated with examples from the field.

Defining Computational Thinking

More than a decade ago, Computational thinking (CT) was proposed as a new “core skill” for all by Jeanette Wing, noted computer scientist and educator. Since then, the definition of CT in K–12 has evolved through a decentralized system, with independent groups working on CT issues pushing forward simultaneously. One of the greatest challenges in the field is the lack of consensus on a precise definition of computational thinking.

Computational Thinking as a Deconstructed Skill Set

Collective efforts to develop a definition of computational thinking include, among others, workshops in 2010 and 2011 sponsored by the US National Academy of Sciences, the “Shut Down or Restart” initiative undertaken by the Royal Society in 2012, and workshops organized by the Computer Science Teachers Association (CSTA) and the International Society for Technology in Education (ISTE).

The National Research Council differentiated computational thinking from computer literacy, computer programming, and computer applications (i.e., games and simulations). It broadened the term to include core concepts from the discipline of computer science (CS), such as abstraction, decomposition, pattern generalizations, visualization, problem solving, and algorithmic thinking.

The Royal Society (2012) offered a concise definition of computational thinking as “the process of recognizing aspects of computation in the world that surrounds us, and applying tools and techniques from computer science to understand and reason about both natural and artificial systems and processes” (p. 29).

CSTA and ISTE, in collaboration with leaders from higher education, industry, and K–2 education, developed an operational definition of computational thinking as a problem-solving process that includes, but is not limited to, the following elements: (a) formulating problems in a way that enables us to use a computer and other tools to help solve them; (b) logically organizing and analyzing data; (c) representing data through abstractions, such as models and simulations; (d) automating solutions through algorithmic thinking (i.e., a series of ordered steps); (e) identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources; and (f) generalizing and transferring this problem-solving process to a wide variety of problems.

After a systematic examination of what is currently known in the literature, researchers,

particularly those with a CS background, define computational thinking as a thought process that utilizes elements such as abstraction, generalization, decomposition, algorithmic thinking, and debugging. Abstraction is the skill of removing characteristics or attributes from an object or an entity in order to reduce it to a set of fundamental characteristics. While abstraction reduces complexity by hiding irrelevant detail, generalization reduces complexity by replacing multiple entities which perform similar functions with a single construct. For example, programming languages provide generalization through procedures and parameterization. Abstraction and generalization are often used together, as abstractions are generalized through parameterization to provide greater utility. Decomposition is the skill of breaking complex problems into simpler parts. Algorithmic thinking is a problem-solving skill related to devising a step-by-step solution to a problem and differs from coding (i.e., the technical skills required to be able to write code in a programming language). Additionally, the algorithmic notions of sequencing (i.e., developing a series of instructions in an order necessary to perform a task) and flow of control (i.e., using looping, conditionals, and branching to dictate the order in which individual instructions or steps in an algorithm are executed) are also considered important elements of computational thinking. Debugging includes the skill to recognize when actions do not correspond to instructions and the skill to fix errors.

Computational Thinking (in Action) as Practice

As one strand of research focused on defining CT by disaggregating its elements, another emerged that explored the integration of CT into disciplinary learning through its practices. Lee et al. (2011) first suggested that CT skills are developed through practice in three phases as students are using, modifying, and creating technologies. As the use of the term CT gathered momentum, it began to emerge within the disciplines as well, most notably among the eight practice standards within the Next Generation Science Standards.

Weintrop et al. (2016) suggest four types of CT practices: data practices, modeling and simulation practices, computational problem-solving practices, and systems thinking practices. Some US states (including Massachusetts and New Jersey) see computational thinking as the thread running through and connecting digital literacy and computer science standards. The Massachusetts Digital Literacy/Computer Science Standards K–12, for example, includes Abstraction, Algorithms, Data, Programming and Development, and Modeling and Simulation in its Computational Thinking strand.

Working Definition

While there are clearly similarities between these two approaches, the differences are numerous. And as these initiatives operate independently, they run the risk of introducing to the field several disparate (and potentially conflicting) definitions of CT. As a result, although a decade has passed since CT was proposed, there does not yet exist a single precise definition of the concept. Voogt et al. (2015) argue:

For the purpose of conceptualizing CT and integrating it in education, we should not try to give an ultimate definition of CT, but rather try to find similarities and relationships in the discussions about CT. Finding these similarities and relationships will lead to a more concise description of “what matters” in CT and how to integrate it within K–12. (¶ 28)

Today most generally agree that computational thinking means formulating problems and their solutions in a way that a computer can be used as a processor to understand the problem or carry out the solution (Cuny et al. n.d.).

Approaches to Computational Thinking Education

Defining CT as disaggregated elements and defining CT as practices integrated into disciplines yielded two different approaches to CT education: (a) programming-centric approaches to CT education and (b) integration of CT within academic disciplines.

Traditional Programming-Centric Approaches

Unplugged activities. CS Unplugged, originally developed by Tim Bell at University of Canterbury (New Zealand), is a hands-on approach that teaches computational thinking and programming concepts through engaging games and puzzles that use cards, string, crayons, and lots of physical movement. Students learn about binary numbers and algorithms without using computer programming. CS Unplugged gained international attention when first introduced at ACM's Special Interest Group on Computer Science Education in 2007. Since then it has become used worldwide as a way to help youth experience computer science without having to learn programming first. Similarly, the Thinkersmith curriculum introduced a stand-alone set of unplugged activities for K-8 specifically designed to provide students with strong computer science foundations without using computers. Lessons in this curriculum, such as Binary Baubles, use materials found in games and crafts to teach authentic computer science concepts.

Building-block programming approach. The building-block programming approach deploys Logo or Logo-like programming languages, such as Scratch, to teach young students various computational thinking skills, such as abstraction, generalization, and algorithmic thinking. In these building-block programming environments, one creates computer programs by simply snapping graphical blocks together into stacks which represent sequences of instructions. In addition, these environments are usually "low floor" (easy to learn how to use) and "high ceiling" (affording the development of complex and sophisticated programs), allowing children to engage in rich programming activities with them.

Tangible programming. Tangible programming makes programming more direct and less abstract for young children by combining computer programming and tangible interaction using physical objects to interact with the computer. Tangible programming tools include: T-Maze, Tern, Toque, and Twinkle.

Digital game design and creation. A fourth approach for teaching computational thinking is digital game design and creation. According to this approach, learners can easily create objects

with visual representations and assign properties to them. Similarly, cMinds Learning Suite is a learning intervention that uses game-based visual programming toward building computational thinking skills. In studies that adopted cMinds Learning Suite in different European countries, learners who used this tool showed high motivation in engaging in computational thinking activities and improved problem-solving skills. Computational thinking tools such as agent cubes, spreadsheets, Mindmap, Boxer, and Logo have been shown to minimize the need for end users to write lines and lines of code and to simplify the ways students across disciplines are able to engage in computational thinking and further develop these skills.

Robotics. Educational robotics constitutes an attractive approach for developing computational thinking, because learners can directly interact with a robot and observe the immediate effects of their interactions on the robot's behavior (Angeli et al. 2016). Engagement with robotics through building and programming tangible and/or robotic devices is used by educators to engage learners in active, playful learning activities. Additionally, many studies indicate that engagement with robotics creates a high degree of student interest and engagement in STEM careers; positively influences school achievement; and science degree attainment.

Computer modeling and simulation. Modifying and creating computer models and using models as experimental platforms to run simulation experiments is an approach that has been used to engage students in computational thinking in middle and high school. In this approach, students use abstraction to recreate features of the real-world system that they deem important, implement the behavior of components of the system as algorithms, and analyze the data generated from running simulations to engage in argumentation from evidence. Results from a research study showed that after modeling and simulating a phenomenon, students were able to propose using computer simulation and describe the potential use of abstraction, automation, and analysis in a hypothetical study of a novel community issue (Lee 2011).

Disciplinary Approaches

As CT integration efforts increased, so did interest in what CT looks like in service of the disciplines. Building on greater recognition of the role CT plays in disciplinary learning, the National Science Foundation (USA) funded a program called STEM +Computing to address “the urgent need to prepare students from the early grades through high school in the essential skills, competencies, and dispositions needed to succeed in a computationally-dependent world through a strong foundation in computing and computational thinking through the integration of CT in STEM teaching and learning” (National Science Foundation 2017).

To guide teaching and learning of CT within the disciplines, NSF sought a new kind of computational thinking framework, one which captured and clarified what students were able to do using CT – and less able to do without it. Working with examples from more than 50 CT researchers and practitioners, Malyn-Smith et al. (2018) proposed five core “elements” that mirror powerful practices in CT-integrated fields (e.g., computational biology, computational chemistry, chemo- and bioinformatics, and computational astrophysics). These elements describe what CT looks like when integrated within disciplines and include the following: (a) understanding (complex) systems, (b) innovating with computational representations, (c) designing solutions that leverage computational power/resources, (d) engaging in collective sense making around data, and (e) understanding potential consequences of actions. This work provides a strong rationale for teaching students computational sciences to prepare them for participatory citizenship in a digital world and for success in tomorrow’s workplace.

Assessing Computational Thinking

While it is generally recognized that little research and development has been done to assess students’ CT capacities, the field is moving forward. In a brief overview of current literature on CT assessments, Grover 2017 described a range of approaches used to assess student learning. While progress in developing assessments for

specific computer science courses that teach computational thinking (e.g., CS Principles, Exploring Computer Science), researchers have found that assessing CT through programming has been challenging. Analyzing students’ artifacts is time-consuming and subjective, driving the development of tools such as Dr. Scratch. However, Grover also notes that it soon became clear that the existence of computational constructs in students’ code did not always translate into students’ CT competence. Rubrics developed to assess algorithmic thinking, abstraction, and code was found to be cumbersome. Innovators turned to gaming environments to assess CT and simulations to assess CT within a disciplinary context (e.g., science). Multiple-choice tests, providing opportunities for large scale assessments, were developed and are being used to assess students’ understanding of programming and computing concepts in countries requiring compulsory CT education. Artifact-based and scenario-based interviews of students were able to detect near transfer of computational thinking to solving new community problems, but this method is too time-intensive to be carried out in large scale.

While most efforts have focused on assessing the disaggregated CT elements identified in the discussion of defining CT above, new questions arise when considering CT from a disciplinary perspective. Do we assess the disaggregated elements of CT (e.g., abstraction, algorithms, and programming)? Or, do we assess students’ application of computational thinking within a context or discipline as they demonstrate understanding of complex systems, innovate with computational representations, or engage in collective sense making around data?

Current Challenges/Issues

Teaching and learning CT and integrating it across the curriculum face challenges at both the systems and implementation levels. Systemic challenges include developing a consolidated understanding of computational thinking, comprehensive integration of CT across the curriculum, systemic rollout, and policy support (Bocconi et al. 2016, p. 7).

At the implementation level, CT becomes a low priority when it is not required as part of compulsory education. Limited access to technologies (Internet capacities, funds for technology/robotics, technology consumables purchases, and maintenance) limits students' exposure to CT skill-building opportunities. Few jurisdictions offer computer science teacher licenses/ endorsements, which in turn limits the number of highly qualified CS teachers available to teach CT skills and integrate CT effectively across the curriculum. Teachers new to computer science and computational thinking require costly comprehensive programs of professional development over an extended period of time to become fully competent and comfortable with their role in teaching CT and integrating it across their curricula. Furthermore, with limited time in the school day, whether or not CT is included as a requirement for compulsory education, tensions arise when teachers are asked to integrate CT into an already crowded curriculum.

Teaching/learning issues include ongoing questions around when and how (and how early) to teach concepts such as abstraction and the basics of computer programming. Is CT best taught through programming or through the disciplines? How should teachers scaffold CT and CS skills/knowledge, integrate computational sciences, and use computational tools to build bridges between school and future work when tools, techniques, and practices are changing with rapid technological advances? What needs to be included in the teaching and learning of CT (and CS) in light of the rapid rise of the machine age? And, of course, what should we assess in CT (disaggregated elements or application within disciplines), and how should we assess it?

Conclusions

A recently developed/formalized field, computational thinking is gaining widespread support as a core skill needed for full participation in a digital society as our world moves towards the Human-Technology Frontier. CT's rapid evolution has created challenges which, currently, are being

addressed world-wide through a decentralized system of research and development. These challenges include the evolution of a common definition of CT and agreement on various models of CT teaching, learning, and assessment. Although great gains have been made the past 15 years, much more needs to be done. In addition to developing a shared understanding of CT, comprehensively integrating CT into curricula, and rolling out/scaling CT efforts nationally, we recognize that in a rapidly changing world driven by technology we must find ways to speed the research/practice cycle to ensure that the skills/knowledge our students are learning in school today will advantage them in tomorrow's world. With increased opportunities for international networking and research/practice collaborations, together we can meet the challenges that rise from the global decentralized system of research, development, and practice of computational thinking.

Examples of Useful Computational Thinking Resources

- Center for Computational Thinking, Carnegie Mellon University. Jeannette Wing's research/practice home for computational thinking. <https://www.cs.cmu.edu/~CompThink/resources/education.html>
- CIRCL CENTER, serving the U.S. National Science Foundation's cyberlearning community. <http://circlcenter.org/computational-thinking>
- Computational Thinking at School (CAS) Barefoot. U.K. site for CT resources for primary schools. <https://barefootcas.org.uk/barefoot-primary-computing-resources/concepts/computational-thinking/>.
- CSTA (Computer Science Teachers Association), serving CS teachers world-wide. <https://www.csteachers.org/page/CompThinking>
- Google Education on Computational Thinking. <https://edu.google.com/resources/programs/exploring-computational-thinking>
- ISTE (International Society for Technology in Education). Assists teachers world-wide to use

technology to solve problems. <https://www.iste.org/explore/articleDetail?articleid=152>

- K–12 CS Framework on Computational Thinking. <https://k12cs.org/computational-thinking>
- Shodor Institute. <http://www.shodor.org/>

For more information on Computational thinking, explore the work of:

- Jeanette Wing – Carnegie Mellon University; Microsoft.
- Charoula Angeli – University of Cyprus, CT in early grades and teacher professional development.
- Michal Armoni – Department of Science Teaching, The Weizmann Institute of Science, Israel.
- Philip Bell – University of New Zealand; CS Unplugged.
- Karen Brennan – Harvard University; Scratch Education.
- Stefania Bocconi – Joint Research Centre of the European Commission.
- Michael Caspersen – Aarhus University, Denmark; CT in practice.
- Jill Denner – ETR; CT, Girls and Gaming.
- Diana Franklin – University of Chicago; CT trajectories, Design elements.
- Shuchi Grover, – CT assessments.
- Irene Lee – MIT; CT, teacher professional development, and modeling and simulation,
- Joyce Malyn-Smith – EDC; CT through the disciplines.
- Fred Martin – UMass Lowell, CT through CS and the disciplines.
- Bob Panoff, – Shodor Institute on Computational Sciences, computational tools.
- Alex Repenning, – University of Colorado Boulder, CT tools and game design.
- Chris Stephenson – Google Education.
- Joke Voogt – University of Amsterdam, the Netherlands.
- David Weintrop, – CT and Mathematics and Science classrooms.
- Aman Yadav – Michigan State University; CT and pre-service teacher education.

Cross-References

- ▶ Algorithmic Thinking in Primary Schools
- ▶ Computing Education, Outcomes of
- ▶ Curricula in Computer Science
- ▶ eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding
- ▶ Mobile Computing and Mobile Learning
- ▶ Modeling of Games and Game Strategies
- ▶ Problem-Solving in Computer Science, Learning from a Gifted Peer
- ▶ Programming and Coding in Secondary Schools
- ▶ Teaching and Learning Computational Thinking and Coding Skills
- ▶ Teaching with Computing, Educational Games

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Computer-Assisted Instruction, Changes in Educational Practice as a Result of Adoption of ICT

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Introduction

Over the last two decades, information and communication technologies (ICT) are becoming more and more important to organizations across the world. ICT for education has become increasingly influential nowadays, more than ever before. The adoption rate of ICT by higher education institutions has been rapid throughout the world, as tools for teaching, curriculum development, staff development, and student learning (Kumpulainen 2007; Usluel et al. 2008). Though ICTs are capable of improving the quality of teaching and learning, the benefits of ICTs are poorly conceived (Surry and Farguhar 1997). Not much is known about how computer systems affect learning (Koszalka and Ganesan 2004) or change in teaching practice (Becker and Jokivirta 2007). A critical review of existing literature on changes in educational practice is offered here, from a perspective of computer-assisted instruction (that, from the teachers' perspectives).

Generally, ICTs are developed to design, store, retrieve, and share information, as well as to communicate with peers, teachers, and other learning partners. ICTs are considered by Rouet and Puustinen (2009) as a means to implement different forms of constructivist, problem-based learning situations. It is becoming more and more important for education institutions to apply ICTs to facilitate learning, enhance teaching, and reduce educational costs (Pituch and Lee 2006; Selim 2007) so as to integrate ICTs in their instructional strategies. These approaches include delivering practice quizzes, lecture notes, other course materials, and announcements through web-based learning systems.

Changes in Educational Practice

Web-based learning (also known as e-learning) is defined as a learning process using web-enacting technologies to encourage interaction and communication between students and teachers (Gunasekaran et al. 2002). Various networking technologies (e.g., WebCT) and online resources are used as e-learning initiatives to support classroom-based learning and distance learning. Ngai et al. (2007) argue that web-based learning systems provide a platform to facilitate teaching and learning as well as new ways for conducting courses and distributing course materials. For years, web-based learning systems have been extensively adopted in education institutions. Changes in the educational practice are reflected in the perceptions of web-based learning systems which have been associated with interactivity, collaboration, and flexibility (Macedo-Rouet et al. 2009).

One of the major changes in educational practice is electronic delivery of lectures (also known as “e-lectures”). An e-lecture is not just a supplement of traditional teaching when a lecture was missed or for revision purpose (Brotherton and Abowd 2004) but also a means of distance learning (Mckinney et al. 2009). Besides using Microsoft (MS) PowerPoint presentations for delivering lectures (Fisher 2003), lecture audio recording software accompanied with MS PowerPoint slides are employed to form navigable “e-lectures” which makes the online lecture entirely available. More and more universities are adopting e-lecture recording technologies to solve web-learning problems (Rui et al. 2004). In fact, an e-lecture with interaction and navigation features has been found to yield better results when compared with a traditional lecture with the same content (Evans et al. 2004). Previous research shows that audio-visual synchronized presentations can be more effective than stand-alone MS PowerPoint presentations or audio files of the same content (Latchman et al. 2001). The work of Khadra et al. (1995) observes that students appreciate the opportunities and flexibility provided by e-lectures and the useful features of electronic learning tools. Other research studies

conducted by Tvedten et al. (1993) and Susskind (2004) also show that students prefer e-lectures. However, in comparing e-lectures with traditional lectures, the latter is more efficient, since the lecturer can keep more control over student learning by designing appropriate teaching strategies (Griffin et al. 2009) to deliver knowledge to a large group of students, although it is constrained by time and place.

Another major change concerns student engagement with web-based content materials which is highly facilitated by interactive multimedia (Kekkonen-Moneta and Moneta 2002). Past researchers observe that web-engaged students achieve high-order learning outcomes than face-to-face students (Maki et al. 2000). Students are pleased with web-based courses because of the interactive quizzes (Maki et al. 2000), interactive course content with self-assessment questions (Evans et al. 2004), and multimedia being more interesting than traditional lectures (Yazon et al. 2002). They perceive the web-based courses as more effective than the face-to-face courses. Several researches have concentrated on collaboration, for example, Oliver and Omari (2001) identify that web-based courses enable students to communicate with group members on aspects of problem-solving. Lockyer et al. (2001) argue that web-based courses allow keeping a record of discussion. Web-based learning motivates students to contribute more time in their learning, especially when the system creates possibilities for them to communicate with other students and teachers (Arulchelvan and Viswanathan 2006). However, web-engaged students have to adjust to a new learning experience when attending the web-based courses.

Despite the fact that web-based learning systems can be more effective and flexible than traditional approaches at imparting information (Holt et al. 2001) and do not hinder the learning process (Dewhurst and Williams 1998), the majority of students have a preference towards traditional approaches. As compared to a face-to-face course, students feel that more effort is required for learning in a web-based course (Maki et al. 2000). Lockyer et al. (2001) find that students are dissatisfied with the lack of

chances to ask questions and receive feedback from the lecturer in web-based environments. Though they realize that a web-based course is more effective than a face-to-face course, they still prefer the traditional face-to-face course. These students may well be those who are unfamiliar in using new technologies or they are accustomed to conventional teaching and learning approaches. Hence, students' adaptation to the e-learning environment becomes an issue that may affect their learning process. They need to use the Web to complete the learning activities and achieve learning outcomes and objectives (Ally 2002; Ritchie and Hoffman 1997). Thus, the changes in educational practice resulting from adoption of ICT are not without pitfalls.

Another major change focuses on the information system of web-based learning. Indeed, both teachers and students contend that information and communication technologies enhance learning (Lonn and Teasley 2009). The transmission of course materials and announcements is highly praised, as they help teachers to distribute information efficiently to students and promote communication between teachers and students. Similarly, teachers' teaching performance can be enhanced as a result of using the information acquired through web-based learning systems (DeLone and McLean 1992). Although with the help of the tools teachers save much time on information search, administrative work, and transmission of announcements, they can spend extra time in using the tools to develop more active learning (Herse and Lee 2005; West et al. 2007). The interactive tools enable students to read the online information in advance and be better prepared for discussion, analysis, and other learning activities. The tools help teachers to engage students in deep learning during class and extend the activities outside the classroom (Lonn and Teasley 2009). It was estimated in a recent survey that not less than 100,000 students in the United States use the Web for submission of their assignments (Bonham et al. 2003). Though it is evidenced that websites with information search features help students locate information and get better learning outcomes, few investigations have been done on the use of

web-based learning systems from an information system perspective (Pituch and Lee 2006; Toral et al. 2005, 2007).

Web-based learning systems facilitate not only the transmission of information but also the management and facilitation of student learning (Coaldrake and Stedman 1999). However, evidence of negative effects of web-based course delivery does exist. When students find it difficult to ramble through the course content on the Web, they lose interest in reading it (Evans et al. 2004). Despite the efficient information delivery, students prefer to print online materials even though they do not resist web-based courses (Bonham et al. 2003; Evans et al. 2004). In fact, they perceive printed notes as being faster to read, easier to annotate and highlight (Martin and Platt 2001), and can be carried anywhere (Martin and Platt 2001). Most probably students' choices of web-based resource are based on whether it provides them the highest possibility of passing the examination rather than it involving technology (Huon et al. 2007). In essence, students care about how Web tools are used rather than whether they are used or not (Holm et al. 2003).

Other negative perceptions of web-based learning systems relating to poor reliability of technology such as broken links, servers not responding, long download times, and insufficient access to computers have been observed by Oliver and Omari (2001). Students prefer using a table of contents to a Web menu as reading long texts on screen is tiring (Macedo-Rouet et al. 2009). They find it more difficult to understand long texts from screen than paper (Murphy et al. 2003). This finding matches with other research results on reading from screen (Eveland and Dunwoody 2001; Macedo-Rouet et al. 2003). Consequently, the increasing rate of users is not as fast as anticipated, though web-based learning systems are considered a useful tool for facilitating teaching and learning activities.

The last major change relates to the assessment features of web-based learning systems. Empirical evidence shows that a computer-based test is better than the paper version of the same test, though paper-based tests have been considered useful in education for a long time (Elton 1970). Clariana

and Wallace (2002) argue that paper-based and computer-based versions of the same test obtain different results. Tests that require organization of elements obtain higher scores with the computer (Threlfall et al. 2007). More exploratory trials can also be undertaken with computer-based test than on paper. However, the display of a computer-based test may require intensive interaction to switch between items, and increased cognitive load may lead to higher concentration on each single item (Macedo-Rouet et al. 2009). In terms of concentration, long reading comprehensive tests are deemed to be ineffective with the computer (Paek 2005). In summary, it has been concluded that different media afforded in tests may affect the performance.

Past studies attempt to find out whether web-based learning systems change teachers' pedagogical practice and students' preferences for how they learn. To enable institutional innovations in learning and teaching, more interactive forms of teaching and learning are essential for supporting constructivist-based learning (Dutton et al. 2003; Lipponen et al. 2004). Teachers have to learn how to use the tools and change their teaching practice to facilitate students' learning with those tools (Bender 2005; Gaensler 2004). When becoming familiar with the technology, teachers should use the interactive features more in their teaching practice to encourage active learning (West et al. 2007). Aiming at facilitating interaction among students, they should change their practice by avoiding immediate intervention in online discussions (Topper 2003). They should consider using reflective dialog such as writing prompts and teacher-supplied models of "good" messages to promote student engagement in reflection and discussion among themselves. Carmean and Haefner (2002) argue that web-based tools can encourage students to experience a deeper learning process by sharing their own representation of the new knowledge with their teachers or peers. Web-based learning systems act as an activator for self-reflection that helps to ease passive learning to become active (Herse and Lee 2005).

Improvements in the Quality of Teaching and Learning

Improvements in the quality of teaching and learning as a result of adoption of ICT depend on three apparent variables. These major variables include web-based learning design, pedagogic strategies, and computer literacy; these may contribute to better web-based learning performance through development of appropriate interactions with the learning environment (Freitas and Olive 2006).

Unlike traditional approaches, web-based learning can be student-centered, knowledge-centered, assessment-centered, and community-centered (Lowyck and Poysa 2001). The roles of teachers and students in this way have been changed. The teacher has become a learning facilitator with little (or less) control over students' learning behavior. Students' learning performance depends on their willingness to engage in active learning (Martens et al. 2004; Moreno and Mayer 2000). Despite the shortcomings of insufficient social presence or lack of verbal communication such as face-to-face responses (Francescato et al. 2006; Horn and Friedrich 2003) that have been remedied by audio-visual telecommunications such as Skype and MSN, students still lack incentives to participate actively in web-based learning that affects their performance (Horn and Friedrich 2003). To motivate students' learning, teachers need to include challenges for students, and means for cultivating cooperation and organizing the learning community in a web-based learning environment. Stimuli in the learning environment are considered as crucial to facilitate students' knowledge acquisition (Nonaka and Takeuchi 1995; Nonaka et al. 1998). It is concluded that the web-based learning design should include project-based and problem-based tasks or activities to stimulate student participation and active learning (Horn and Friedrich 2003; Pearson 2006).

To improve learning performance, a learning atmosphere should be created to encourage

students' engagement in collaborative learning. ICTs have enabled a collaborative learning environment at the expense of student motivation and engagement (according to Fu et al. 2009). Web-based learning can offer a productive learning atmosphere since collaboration among students becomes an effective learning strategy in the growth of knowledge. The learning atmosphere can encourage students to develop higher analytic and synthetic skills, thus constructing greater overall knowledge (Fu et al. 2009). Students' attitudes and achievements can be directly affected by the cooperative interactions among them (Rosenfield et al. 1981). Through manipulating pedagogic strategies, teachers can create an atmosphere with different degrees of social presence to achieve different degrees of learning enjoyment (Fu et al. 2009). Through the development of ICTs, a convenient and inexpensive online communication media is available. Unlimited resources can be made accessible online by teachers and students outside the courseware. If ICTs are used effectively, the web-based environment provides a high capacity for knowledge acquisition (Fu et al. 2009). However, students' computer literacy is crucial to effective collaborative learning. They must possess some prerequisite skills to enable them to complete web-learning activities. The less-skillful students should receive training before or during the learning process. In this way, students' computer literacy is considered as a variable influencing the effectiveness of web-based learning. Thus, teachers should always examine students' comfort and competence with the intervening technology and provide safe environments for them to increase their sense of computer literacy.

Conclusions

The adoption of information and communication technologies (ICT) has brought forth potential changes in educational practice – particularly in terms of computer-assisted instruction. These

changes can help to improve the quality of teaching and learning. Web-based learning systems can provide more reflective and useful interactions among students, teachers, and resources (Picciano 2002). ICT has assumed an enormous importance in improving the quality of education at all levels and has played a major role in educational endeavors towards enhancement as well as enrichment. Web-based learning systems provide a nontraditional learning and teaching environment. Different teaching strategies, activities, and technologies are used to create a dynamic learning community. A review of the literature suggests that integration of the new technologies and instructional strategies in education further enhances the quality, accessibility, and affordability of web-learning experiences.

Web-based learning delivery, depending on new technologies, has been largely enhanced. The challenge to practitioners is to explore what styles, strategies, methods, and activities are most effective, in terms of cost and learning, in developing and delivering quality web-based learning courses. As expected, web-based learning, similar to other forms of quality learning, being knowledge, community, assessment, and learner-centered (Anderson and Elloumi 2004), can enhance the important function of interaction in various ways among the participants. The task of the web-based course designer and teacher is to select, adapt, and facilitate educational activities that maximize the affordances of the web-based learning through feedback, assessment, and reflection. In doing so, they will help to create educational experiences that result in high levels of learning by all participants.

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Computer-Assisted Learning

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Synonyms

Computer-assisted instruction; Computer-aided instruction; Computer-based learning; Computer-mediated learning

This contribution explores computer-assisted learning (CAL) from a number of different angles. First, it discusses the many synonyms that exist for the use of information and communication technologies (ICTs) in education. Within these synonyms are concepts which often hide subtle but important differences from both a technological as well as a pedagogical/educational point of view. It proceeds with a short history of CAL. While CAL as an entity was first used in the early 1960s of the previous century (1960s), the concept underlying its use has roots dating back to the beginning of that century. The third and final part will focus on the effectiveness of CAL in education which will lead to an adaptation of the current definition.

What's in a Name?

In their *Dictionary of Computing*, Daintith and Wright (2008) describe CAL as

[a]ny use of computers to aid or support the education or training of people. CAL can test attainment at any point, provide faster or slower routes through the material for people of different aptitudes, and can maintain a progress record for the instructor. (Online entry)

This definition has changed through the course of time as the computer itself has changed from a bulky, building-large behemoth of tubes and wires to something that fits into your pocket and can be

even smaller. In the 1960s, computer use was first introduced in education. In this first phase of CAL, the computer was a mainframe which was connected to learners in specifically designed “classrooms” via terminals that were relatively far away from the mainframe computer. In this phase, the computer was primarily used as a knowledge-bank of questions which students could use for self-assessment of their knowledge. Using computers was extremely expensive and cumbersome and was only available for a “happy few.”

In the 1980s and 1990s, CAL was often used to refer to the development of either a single computer program or a series of programs which replaced more traditional methods of teaching. This was the direct result of the introduction in August 1981 of the IBM PC (personal computer) followed by the Apple II shortly thereafter. A mainframe computer was no longer needed to use computers for educational purposes and each student could work at her/his own PC in school or, for those pioneers, at home. This period also saw the introduction of what is now called computational thinking/coding with the launch of LOGO by Seymour Papert and his group at the Massachusetts Institute of Technology Artificial Intelligence Laboratory where, with the aid of PCs/microcomputers children in classrooms received an initiation to computer programming skills, turning it from an abstract activity only carried out by specialists into a concrete, real activity that could be carried out by students to program the movement of a robotic turtle.

This second wave was followed by a third wave ushered in by the introduction and availability of the Internet/World Wide Web where computers and people worldwide became connected to each other. This third wave also brought us tools such as email, webpages, blogs, etc. This broadened the concept of CAL to include, for example, web-based tools such as online learning environments, opening the door to online databases, making learning analytics a possibility.

The present wave is shaped by the availability of mobile devices (e.g., smartphones, tablets), semi-intelligent peripherals (e.g., augmented and virtual reality glasses, motion sensing input

devices, such as the Kinect or the Wii), and seamlessly integrated devices (e.g., the Internet-of-things) where CAL literally can take place any-time and anywhere where there is Internet (and that is virtually anywhere in the world).

Going back to Daintith and Wright's (2008) definition, when it is examined in detail one can distinguish a number of core elements:

- **Use of computers:** while there were analogue computers up to the 1960s, this now implies the use of many different digital media interconnected via the World Wide Web. To update this, it might be better to speak of the "use of multimedia and the Internet."
- **Support the education or training of people:** the "computer" will take up one or more roles and functions of the teacher and/or trainer to offer the learner necessary support and guidance during the instructional or learning event.
- **Test attainment at any point:** the "computer" will keep track of the learning process to determine whether the learner has achieved the goals of the CAL. It often does this by comparing the different products during the learning period with the beginning and end situations. This is related to what is now known as "learning analytics" which can be described as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs." (Ferguson 2012, p. 305)
- **Provide faster or slower routes through the material for people of different aptitudes:** the "computer" provides possibilities to adapt the content of, pace of, and/or approach to learning based on learner progress which is presently determined by learning analytics. The terms now being used for this are adaptive learning and personalized learning.
- **Maintain a progress record for the instructor:** the "computer" is not only facilitated to let the technology adapt to the learner but also to inform the teacher/instructor to be able to adapt his or her approach based on the learning analytics.

Daintith and Wright (2008) also state that CAL is one of several terms used to describe this application of computers. Indeed, there have been many different names given to the use of ICT in education. Some names focus on the kind of technology being used, such as computer-mediated learning, computer-based learning, intelligent tutoring systems, web-based learning, and mobile learning. In these aforementioned cases, there can be an overlap between which technology is used and how the technology is used. And although the terms are often used as almost synonyms, at the same time it is perfectly possible to use mobile technology that is not web-based, to use computer technology that is not mobile or to use web-based tools that are not mobile or other web-based tools that cannot be used on personal computers.

The many names for the use of information and communications technology (ICT) in education can also hide differences between pedagogical and educational views, for example, the not so subtle difference between CAL and computer-assisted instruction (CAI). The difference between learning and instruction is the difference between a focus on the task of the pupil (learning) and a focus on the task of the teacher/teaching (giving instruction). This distinction goes far beyond the use of technology and has deep historical roots going back to the Romantic era (eighteenth century), but this does not mean they can be disregarded. Which name people use for the use of technology in education often discloses a certain vision on or philosophy of education. When using CAL, one comes close to a paradigm of social-constructivism where a pupil must build her or his own knowledge, while CAI could be regarded as a more cognitivist or instructivist approach which puts the emphasis on the need for an expert who can give the necessary support and guidance (Kirschner et al. 2006).

Finally, some of the names are a combination of the two. Take, for example, computer supported collaborative learning (CSCL). On the one hand, there is an emphasis on the technology, namely, the computer or, better stated, computers connected to each other through a network. On the other hand, there is emphasis on the pedagogy, namely, collaborative learning. This is an

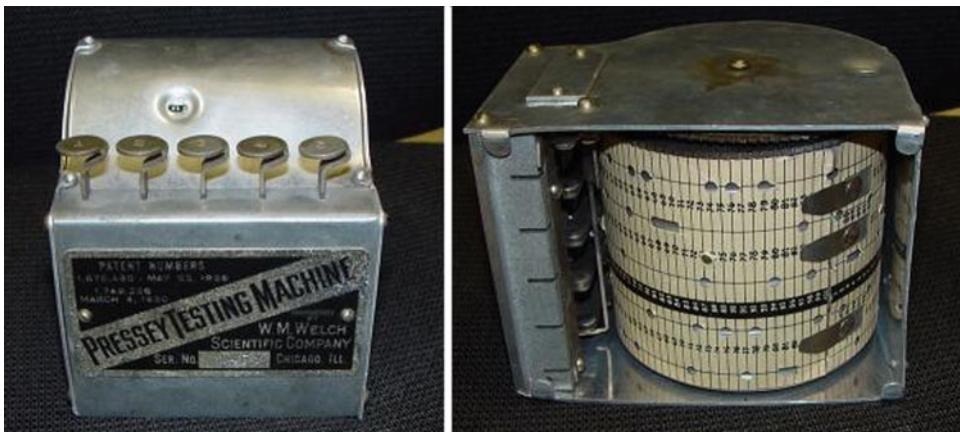
approach to learning whereby a shift is made from learning individually and competitively to learning with others in the context of a team carrying out a task or solving a problem such that the members of the team share authority and accept responsibility for the group's actions.

The Pedagogical and Educational Roots, History, and Near Future of CAL

The oldest roots of thinking about machines helping someone to learn in a way resembling the definition of CAL date back to the first half of the previous century. Edward Thorndike (1912) was one of the first to think along the lines of *providing faster or slower routes through the material for people of different aptitudes*. He specified three conditions or laws that maximized learning. His law of *effect* held that the likelihood of a recurrence of a response is affected by reward or punishment. The law of *recency* held that the more recent something is, the more likely that it will recur. Finally, the law of *exercise* held that stimulus-response associations are strengthened through repetition. In his eyes, and based upon his laws, “[i]f by a miracle of mechanical ingenuity, a book could be arranged that only to him [*sic*] who had done what was directed on page one would page two become visible and so on, much that now requires personal could be managed by

print instruction” (p. 165). But Thorndike did not make such a – mechanical – learning machine himself. The first to do so was Sidney Pressey who developed a mechanical testing machine which he, oddly enough, called the *Automatic Teacher*. What it did was present students with multiple-choice questions, one at a time, that were sequences from least to most difficult. The student could only move on to the next question by answering the previous one correctly. This was intended to lighten the load on the teacher with respect to grading students so she/he could focus on more interaction with the student. While his machine was originally designed to make the testing and scoring of simple multiple-choice achievement tests possible, he soon discovered that it also had instructional qualities closely related to what later became known as programmed instruction as the device could show a predetermined sequence of questions one at a time, through an aperture. The student selected an appropriate answer from a card and pressed a key representing that answer; the selection of the correct answer resulted in the machine prompting a new question for the student (see Fig. 1).

After Pressey, more and different teaching machines were trialed and tested until in 1954 B. F. Skinner wrote his *The Science of Learning and the Art of Teaching*. In this seminal work, Skinner (1954) laid down the basics of his vision on programmed instruction which was then later



Computer-Assisted Learning, Fig. 1 Pressey's testing machine (https://en.wikipedia.org/wiki/File:Pressey_Testing_Machine_1.jpg; https://en.wikipedia.org/wiki/File:Pressey_Testing_Machine_2.jpg)

translated through different incarnations of teaching machines. The most important difference with Pressey's teaching machine – though similar to Thorndike's law of effect – was the strong emphasis that he placed on reinforcement during the learning process (Skinner 1961).

Skinner was inspired by the Socratic teaching method and, thus, he broke down complex lessons into a series of small questions. Each question required the student to respond to it in a way that built upon the correct response to the previous one. In this way, Skinner's machine (see Fig. 2) required students to master one concept before they were able to move onto the next, a type of learning that eventually came to be known as *mastery learning*.

Specific to all of these early teaching machines was their basis on a behaviorist view of learning (actually conditioning) where a stimulus is presented (a unit of preferably new information), a reaction (a response) is required, followed by immediate feedback as to the correctness of the response and which is often repeated to strengthen the connection. Arthur Lumsdaine (1959, p. 164), who researched the use of media and programmed learning, wrote that teaching machines have three basic characteristics:

- First, continuous active student response is required, providing explicit practice and testing of each step of what is to be learned.
- Second, a basis is provided for informing the student with minimal delay whether each

response he makes is correct, leading him directly or indirectly to correction of his errors. Third, the student proceeds on an individual basis at his own rate – faster students romping through an instructional sequence very rapidly, slower students being tutored as slowly as necessary, with indefinite patience to meet their special needs.

The devices thus represent a way of providing a preprogrammed study-practice combination which simulates, in partially or fully automated fashion, the functions of a private tutor in recitation and practice, with immediate correction of errors and feedback to the student.

This first phase of learning machines can be regarded as the behavioristic phase. Though different forms of “computers” were around long before the 1960s – the Antikythera mechanism, for example, has been described as a computer from ancient Greek times (Freeth et al. 2006) – and there have been different learning and teaching machines, the concept of “computer-assisted learning” stems, as stated, from the 1960s of the previous century. While scientific references are older (e.g., Coulson et al. 1962; Glaser 1965; Suppes 1965), the first real mentions of CAL in scientific journals can be found in 1966, after its mention at conferences in 1965 (e.g., The Conference on Computers in Physics Teaching, University of California at Irvine, November 1965) (Based on searches in ERIC and Scholar which resulted in Fowler (1966), Hirsch (1966), and Trump (1966) as oldest sources).

Computer-Assisted Learning,

Fig. 2 Skinner's learning machine (https://commons.wikimedia.org/wiki/File:Skinner_teaching_machine_01.jpg)



Probably due to a combination of resources, perceived affinity of the domain for CAL and political forces that often drive changes in education, the natural sciences (including mathematics and medicine) were the early adopters of CAL. A good overview of this can be found in a special issue of *Computers & Education* in 1992 (volume 19, numbers 1–2). For example, the integration of the computer into medical education was recommended in 1979 by Daniel Tosteson, then Dean of Harvard Medical School, when he proposed that the use of what he called “information-processing devices” be developed as a core component of the medical school curriculum. Michael Hewson, in his seminal work on the use of microcomputers in science education (1984) summed it up as follows: in science education, microcomputers allow students to play a more active role in learning, get individual attention for their specific difficulties, and allow students to control the pace at which they work. Also, physics educators showed a particular interest in CAL (e.g., in Fowler (1966)). Another specific form of CAL, computer-assisted language learning (CALL) stems from the same period (Marty 1981), though the use of computers for language learning was at first limited to universities. CALL makes use of computer technology to aid in the presentation, reinforcement, and assessment of language material – usually a second or a foreign language – to be learned. While originally based upon stand-alone applications on microcomputers, CALL now uses a broad range of technologies and approaches ranging from traditional drill-and-practice programs to virtual learning environment and web-based distance learning with its most recent being mobile-assisted language learning (MALL; Shield and Kukulska-Holme 2008).

After these initial often behavioristic inspired approaches of CAL – see also the link with Skinner and Thorndike – in the 1970s and 1980s a different approach to CAL and CALL could be seen with more Intelligent Tutoring Systems introducing a second rather cognitivist phase. The advocates of this approach argued that all CA(L)L courseware and activities “should build on intrinsic motivation and should foster

interactivity – both learner-computer and learner-learner” (Han 2009, p. 41). In this cognitivist phase, research and development now were directed at finding, studying, and implementing methods and strategies that would bring about specific and desired cognitive processes, for example, assisting learners in selecting information, organizing it into internally consistent concepts, and integrating new with existing knowledge in cognitive schemata so that it would be personally relevant and meaningful. This second phase coincided with the second wave discussed earlier that came from outside education as, from the 1980s onwards; the microcomputers made computer technology more accessible to a broader audience and to educational institutes besides the universities. Warschauer and Healey (1998) describe a third phase as social-constructivist with a strong emphasis on agency (Warschauer 2000). But it can be argued that for this objective of agency, a democratization of microcomputers was not enough; the third wave described as integrating the worldwide web was key for this.

A fourth phase benefited also from the technological evolutions which came with the development of network-based technology, through which people can share whatever and communicate with each other whenever and wherever (Tafazoli and Golshan 2014), which made an evolution possible from a social-constructivist approach to a connectivist approach. This phase coincided with computer technology becoming more mobile, which led to mobile devices such as laptops, smartphones, iPads, and Augmented Reality-devices, with the possibilities of a steady growth of computing power, making it possible to handle large amounts of data, now referred to as Big Data, or as we call it today in education: learning analytics. These kinds of mobile devices, combined with technology as the original definition stated that is able to *test attainment at any point*, can give the user both teacher and learner agency.

A further evolution of CAL can come in the form of the use of artificial intelligence (AI), with smart assistants helping both teachers and students in their teaching and learning process. A

first example was delivered by “miss Jill Watson,” an AI-assistant powered by IBM’s supercomputer Watson that answered email-questions of students of Professor Eric Wilson (Korn 2016).

The Effectiveness of Computer-Assisted Learning

The first law of Kranzberg (1986) states that “technology is neither good nor bad; nor is it neutral.” This is also the case when discussing the effectiveness of CAL. In 2015, the OECD (2015) concluded that more computers do not necessarily mean more learning; it is more important to see how the technology is being used. In his review of the many different meta-analyses on computer-assisted instruction, John Hattie (2009) described a reasonable degree of variability across the overall effect sizes. The advice Hattie gives is that the use of computers is more effective when:

- There is a diversity of teaching strategies.
- There is teacher pretraining in the use of computers as a teaching and learning tool.
- There are multiple opportunities for learning (e.g., deliberative practice, increasing time on task).
- The student, not the teacher, is in “control” of learning.
- Peer learning is optimized.
- Feedback is optimized.

In other words, it is the pedagogy and not the technology that can affect outcome. This is an echo of Richard Clark (1983) who found that research on media showed that when differences between media on learning are found, it is the method that causes the difference and not the medium. He summed this up in his famous quote, “[M]edia are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries cause changes in our nutrition” (p. 445).

A more recent literature-review for The National Bureau of Economic Research by

Escueta, Quan, Nickow, and Oreopoulos discusses the evidence to the present time (2017) on the use of technology in the classroom. For their review, the authors compiled publicly available quantitative research that used either randomized controlled trials or regression discontinuity designs (where students qualify for inclusion in a program based on a cut-off score at pretest). All the studies that were used in the working paper examined the effects of an educational technology intervention on any education-related outcome, which makes this work broader than studies only looking at a learning effect. The working paper included not only the areas of technology access, computer-assisted learning, and online courses but also the less-often-studied technology-based behavioral interventions.

What are the conclusions?

- Access to technology may or may not improve academic achievement at the K-12 (4 to 6-year-olds through 12th grade (12) for 17 to 19-year-olds) level, but does have a positive impact on the academic achievement of college students.
- Online learning courses had the least amount of research that could be examined and showed the least promise of the four areas. However, when online courses were accompanied by in-person teaching, the effect sizes increased to scores comparable to fully in-person courses.

But the most relevant conclusion of the paper was that:

- Computer-assisted learning, when equipped with personalization features, was an effective strategy, especially in mathematics (Escueta et al. 2017).

This last conclusion means that one element of the definition of CAL is key for its effectiveness: *Provide faster or slower routes through the material for people of different aptitudes*, although personalization can go much further than adapting the speed of the learning routes; in this regard, the 2010 National Educational Technology Plan (Office of Educational Technology 2010)

describes personalized learning as “broader than just individualization or differentiation in that it affords the learner a degree of choice about what is learned, when it is learned and how it is learned; this may not indicate unlimited choice, since learners will still have targets to be met.” This element of personalization, its role in effectiveness of computer-assisted learning, and the new possibilities from technology have warranted an adaptation of the definition by Daintith and Wright. A possible amendment could be the following (the modification is in *italics*):

Any use of computers to aid or support the education or training of people. CAL can test attainment at any point, *personalise the learning routes both in speed, complexity and other possible forms of personalisation of learning*, and can maintain a progress record for the instructor.

Conclusion

Computer-assisted learning (CAL) is older than one may think, dating back to the early 1960s of the previous century, with roots dating back to the beginning of the previous century. The meaning and focus of CAL has changed throughout time, shifting from behavioristic, through cognitivist and social-constructivist to connectivist visions, often fuelled by technological evolutions. While many people have put hope in technological breakthroughs making it possible to have better learning results, the actual research shows mixed results.

Cross-References

- [Blended Learning](#)
- [Computer-Based Learning, Computational Thinking, and Constructionist Approaches](#)
- [Distance Learning](#)
- [Mobile Computing and Mobile Learning](#)
- [Mobile Learning and Ubiquitous Learning](#)
- [Multimodal Learning Analytics](#)
- [Teaching with Computing, Educational Games](#)
- [Technology Enhanced Learning](#)

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Computer-Based Assessment

► [Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption](#)

Computer-Based Communications

► [Assisting Elderly Non-computer-Literate People with Computer-Based Communications](#)

Computer-Based Educational Technology

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► [Computer-Based Learning, Computational Thinking, and Constructionist Approaches](#)

Computer-Based Learning

► [Computer-Assisted Learning](#)

Computer-Based Learning, Computational Thinking, and Constructionist Approaches

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Synonyms

[Computer-assisted learning](#); [Computer-based instruction](#); [Constructionist learning environments](#)

Introduction

This entry explores computer-based learning (CBL) designs that are informed by the learning theory of constructionism. First, it discusses different definitions and types of CBL and explores the pedagogical approaches that underpin CBL designs through a brief history of CBL

in education. Next, it elaborates on the role of the constructionist paradigm in CBL and presents different CBL designs that are based on constructionism. Then it focuses especially on the use of constructionist CBL approaches for supporting students to cultivate their computational thinking. The final part discusses the educational challenges and the near future of constructionist CBL.

What Is Computer-Based Learning?

Computer-based learning (CBL) is a term that is used to describe “any use of computer software for the purposes of supporting the process of learning” (Adams 2004). Similarly, the term computer-based learning environment (CBLE) refers to the software that students use and interact with during CBL, and it includes any computer application, tool, or program that is developed and designed to support the learning of a specific subject.

CBL focuses on the individualized self-study of a learner through his/her active engagement in a set of digital activities designed with a pedagogical agenda. Usually, CBL implies the absence of a teacher or a facilitator during the learning process. This doesn’t mean, though, that it is necessarily implemented out of school. In many cases, CBL takes place in the classroom context as part of the curriculum supplementary to teaching (Serin 2011; Adams 2004; Valdez et al. 1999).

Interactivity is a core characteristic of CBL that distinguishes it from other educational media like presentations, video and audio, etc. The learner interacts with the digital learning environment, which responds with feedback, leading to iterative cycles of practice and reflection. In order to support different types of learners, CBLEs are usually designed to provide multiple forms of interdependent representations along with the presentation of information and activities in a nonlinear format. In the literature, we find different categories of CBL according to the type of technology that the learner uses and the level of interactivity between the learner and the digital environment. Some common categories that we find in the literature are the following (Adams

2004; Hackbarth 1996; Serin 2011; Valdez et al. 1999):

- *Drill-and-practice*. Learners answer successive short questions and quizzes. They have to answer correctly each question to progress to the next one; otherwise, they repeat it. This type is usually used to teach segmented content through memorization.
- *Tutorial*. It is similar to drill-and-practice, but it contains more information and educational material. Learners follow a step-by-step guided instruction that provides them with information, examples, and exercises for practice, in order to acquire satisfactory knowledge of specific concepts or skills. In some cases, it is used as a replacement for teaching while in others as a supplement to enhance a student’s knowledge in a certain area.
- *Inquiry*. Learners use digital tools such as databases, spreadsheets, etc. to search, acquire, and synthesize information on a specific subject. This type of CBL engages learners not only with the acquisition but also with the assessment of digital information.
- *Simulation*. Learners explore a real-world phenomenon that is simulated with a model in the digital environment. As they interact with the model and observe the results, they discover the rules, relations, and concepts that underpin the behavior of the simulation. Simulations are usually used in the classroom with the teacher intervening to explain concepts, ask questions, and draw the attention of students to specific points of the model.
- *Programming*. Learners use a programming language to solve a computational problem or to create a digital artifact (i.e., a game, a drawing, etc.).
- *Educational games*. Learners play a digital game that is pedagogically designed to integrate scientific concepts. While they play, learners discover and use concepts and skills through a meaningful and motivating experience for them.

An important element of CBL mainly afforded in the first two categories is the

adaptability to the learner's needs (Moos and Azevedo 2009). In these two categories, educators may use CBL in the classroom for various purposes including (Moos and Azevedo 2009) increasing the productivity of student class work, fostering student interest and motivation, personalizing the learning process, etc. According to different reports (Serin 2011; Moos and Azevedo 2009), possible benefits that CBL can add to the learning process are:

- (a) Enabling students to progress at their own pace by individualizing the learning process (mainly regarding the first two categories).
- (b) Motivating students to participate in the learning process by providing them with a familiar and attractive context.
- (c) Supporting students' self-evaluation and self-reflection by providing immediate feedback.
- (d) Students may connect scientific concepts to their daily lives and their interests.
- (e) Students are actively engaged in the learning process and construct knowledge.
- (f) Apart from the construction of knowledge, it can also help the development of creativity and problem-solving skills.

However, according to studies, the effectiveness of CBL varies between individuals and between different CBLEs. Factors that may affect the learning outcomes of CBL are the personal characteristics of each learner (Moos and Azevedo 2009), like self-efficacy, experience, and prior knowledge, but also the affordances that the learning environment provides to the learner for interaction and active engagement.

Each category of CBL follows a different pedagogical approach and utilizes diverse types of technology. Ellington et al. (as mentioned in Adams 2004) describe three pillars that form a CBL design: (a) the *hardware* that refers to the actual computer and its specifications; (b) the *software* that refers to the computer application or program that is used; and (c) the "underwear" that refers to the pedagogy on which the CBL is grounded. The latter one affects the design of the computer-based learning materials and the level of interactivity that the environment provides to

the students. Since the first use of computers for educational purposes in the 1970s, all three pillars have evolved, and so has CBL.

A Brief History of the Pedagogical Paradigms of CBL

The term CBL was first introduced in the 1970s as an approach of integrating computers in education with the role of tutors, as in the first two categories in the previous section. Back then, personal computers provided the user with very few functionalities due to the technological limitations of that era. The first educational software was mostly textbooks presented in electronic formats like tutorials and drill-and-practice programs that aimed to teach specific scientific concepts to students (Adams 2004; Hackbarth 1996). The design of CBLEs was program-centered and instructionist. They usually provided students with pre-defined educational content structured in a linear way, allowing limited control and interaction to the learner. The dominant pedagogical approach that underpinned CBL designs at that time was *behaviorism*, which focused on breaking learning into small achievable steps, with students having to master each one sequentially (Adams 2004; Valdez et al. 1999).

Technological developments that followed led to a new paradigm for CBL that emerged from cognitive psychology. The revelatory paradigm, as it is called by Adams (2004), is based on *discovery learning*, and it promotes students' exploration and discovery of rules, laws, and relationships in a given simulation or model. Cognitive approaches to CBL emphasize how students know rather than how they respond, and they focus on the development of higher-order thinking and problem-solving skills through planning, analyzing, and communicating.

In the early 1970s, Seymour Papert together with Feurzing built the Logo programming language and introduced the Turtle Geometry learning environment to mathematics education (Papert 1980). The Logo language made programming accessible to every child in the form of an expressive medium with which to do

mathematics. However, it was not until the early 1980s that schools started to integrate Logo programming into their curricula. During the 1980s, many schools showed great enthusiasm for teaching their students mathematical and programming concepts with Logo. Together with the spread of Logo programming in schools, an epistemological approach called *constructionism* was developed by Papert, resulting in a number of new approaches to CBL.

However, by the late 1990s and early 2000s, many schools turned away from programming, mainly because of a lack of subject-matter integration and a lack of qualified instructors (Noss and Hoyles 1996). When software tools with dynamic manipulation and icon-driven technology appeared, programming was seen as a kind of unnecessary noise when compared to doing interesting things with digital media (Kynigos 2015). As a result, CBL environments started to use hypermedia and interactive visual technologies to attract students, leaving aside the constructing part.

During the last decade, however, we are facing a comeback regarding the interest in programming as a means of expression (Kafai et al. 2014) and of constructionist CBL designs. This time, programming is considered an integral part of a new perception of computational literacy. Recently, renewed perceptions about the value of computer programming have become popular; that every child can and should learn to write code as a way to develop their computational thinking. The idea of computational thinking that Wing described in 2006 as “a set of thinking skills, habits and approaches that are integral to solving complex problems using a computer and widely applicable in the information society” is now considered as a necessary expressive skill for twenty-first-century students (Kafai et al. 2014; Lee et al. 2011). In this context, constructionism has a lot to offer both as a pedagogy that underpins computer-based activities and as a theory of design (Kynigos 2015) that guides the development of new computer-based learning environments.

Constructionist Approaches to CBL

Constructionism endorses the main principles of the constructivist learning theory; that knowledge is not determined information communicated from a transmitter (i.e., teacher) to a receiver (i.e., student), but it is actively constructed by the learners according to their own experiences and interactions with the world (Papert 1980; Ackermann 2001; Kynigos 2015). Cognition is adaptive, and conceptual changes may emerge as a result of the learner’s evolving organization of the experiential world.

Constructionism shifts the focus from understanding the conceptual changes that occur at different stages in the life of the learners to the actual meanings that the individual learner generates in specific contexts (Kynigos 2015). It emphasizes on how the learner forms, communicates, and reforms meanings and powerful ideas while he/she interacts and constructs artifacts with digital tools. For constructionism, *a key concept in learning is the expression of personal feelings and ideas* (Ackermann 2001), and digital media are one of the means to support this expression through different representational forms. With the mediation of digital technology, students can access and explore some very *powerful ideas* which, with other means, would be inaccessible or difficult to understand (Papert 1980).

In constructionist approaches to CBL, the software and its affordances become tools for the learner to construct with and “objects to think” with (Papert 1980). In that context, the aim of CBL is not to transfer the knowledge from the computer to the learner, as happened with the behaviorist approaches, but for the learner to produce the knowledge using the computer as a tool. Constructionist CBLEs are designed to provide the learner with the appropriate affordances to access powerful ideas and enable actions like building a model, reflecting on it, and sharing the model with others (Noss and Clayson 2015).

Constructionism was initially perceived as an approach to an experiential learning process of the individual, or at least without much emphasis on

interaction between humans. Papert himself, however, elaborated on the process and the value of a learner publicizing their construction before it was considered a final artifact, in order to share and discuss its features and properties during the process of improving or changing. It was this discursive aspect that gave rise to a socio-constructivist approach to constructionism elaborated by other researchers such as Kafai et al. (2014). In constructionist approaches, the sharing of the constructed artifact in a community is as important as its construction, as it affects a learner's understanding and generation of meaning. Based on the Vygotskian sociocultural perspective of learning, Borba and Villarreal (2006) developed the "Humans-with-media" approach to describe how the engagement with a task through digital media can create and transform collectives of learners which affect the reorganization of thinking and the generation of meaning of the individual learner. According to their view, digital media result in dialogue and discussion about the learning task, leading the learner to reform his/her understanding and to reengage with the task from a newly situated perspective. In that sense, digital technology has a mediating role to thinking, similar to the one that language has in Vygotsky's approach. This social aspect of the learning process underpins many designs of CBL environments, which emphasize sharing, exchanging, and evaluating the constructed artifacts with digital media.

Noss and Clayson in their article "Reconstructing Constructionism" describe six characteristics of a constructionist design agenda that should underpin computer-based learning environments. The first is the idea of *modelling*, referring to the process of building, reflecting, and debugging, through which learners can develop internal knowledge structures about powerful ideas. The second is the provided *accessibility* to the modelling process so that the learners are aware of the existing models and how they are created. The third is the *layering* of scientific concepts by integrating increasing problem-solving complexity into the learning

environment. The fourth characteristic is to carefully design a digital environment that is *aligned with the learners' agenda and culture*. The fifth is the *representation of the knowledge* in a language with which learners can express themselves. And finally, the sixth characteristic is to promote *collaboration* by enabling learners to share artifacts and ideas and to communicate both in the same space and at a distance.

In the next section, five constructionist CBL approaches that integrate all or most of the above elements and have been implemented and studied in a classroom context are described. For each one, examples of widely used CBLEs and relative studies with students are presented.

Microworlds

One of the first constructionist approaches used in CBL designs was the idea of microworlds. Papert (1980) introduced the term microworld to describe a digital artifact "designed to invite engagement in the activity, ownership of ideas and learning style and exposure – i.e., expressing one's own ideas to others – for exploration, negotiation and communication" (Healy and Kynigos 2010). A microworld simulates a real-world situation or phenomenon and provides students with functionalities to explore, change, and extend the initial rules and behaviors of the simulation. As we read in Balacheff and Kaput (1997), there are two basic features that constitute a microworld:

- (a) *A set of primitive objects, elementary operations on these objects, and rules expressing the ways the operations can be performed and associated.*
- (b) *A domain of phenomenology that relates objects and actions on the underlying objects to phenomena at the "surface of the screen." This domain of phenomenology determines the type of feedback the microworld produces as a consequence of user actions and decisions.*

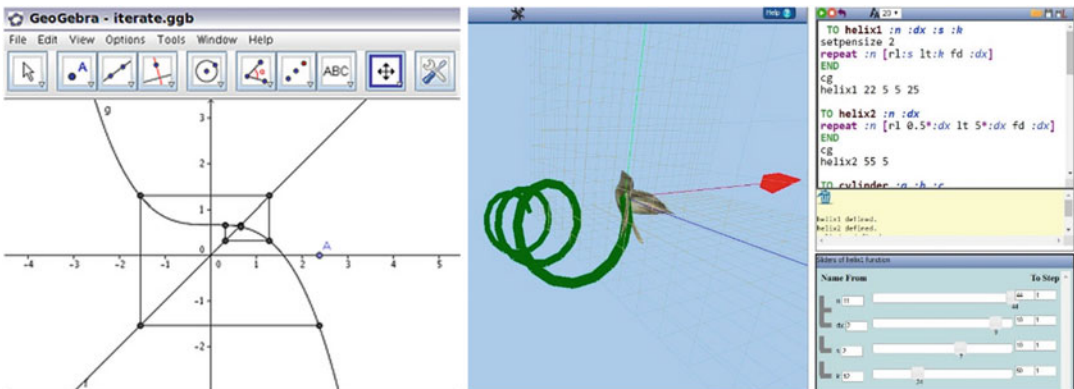
Microworlds allow learners to use and modify their rules and objects and to create new ones. Thus, the learners have simultaneously the roles of user and designer. The first microworlds focused mainly on the exploration of

mathematical concepts with the use of the Logo programming language (Papert 1980). In the following years, students of different ages in many schools programmed, explored, and changed mathematical models in microworlds designed with the Logo language or with other Logo-based languages like StarLogo (Resnick 1997; Noss and Hoyles 1996). The relative research showed that the characteristics of the Logo language combined with the representational structures provided by a microworld facilitated students' meaning generation about complex mathematical concepts and ideas (Papert 1980; Kynigos 1995). Until today, the microworlds approach has a significant impact on CBL for mathematical education.

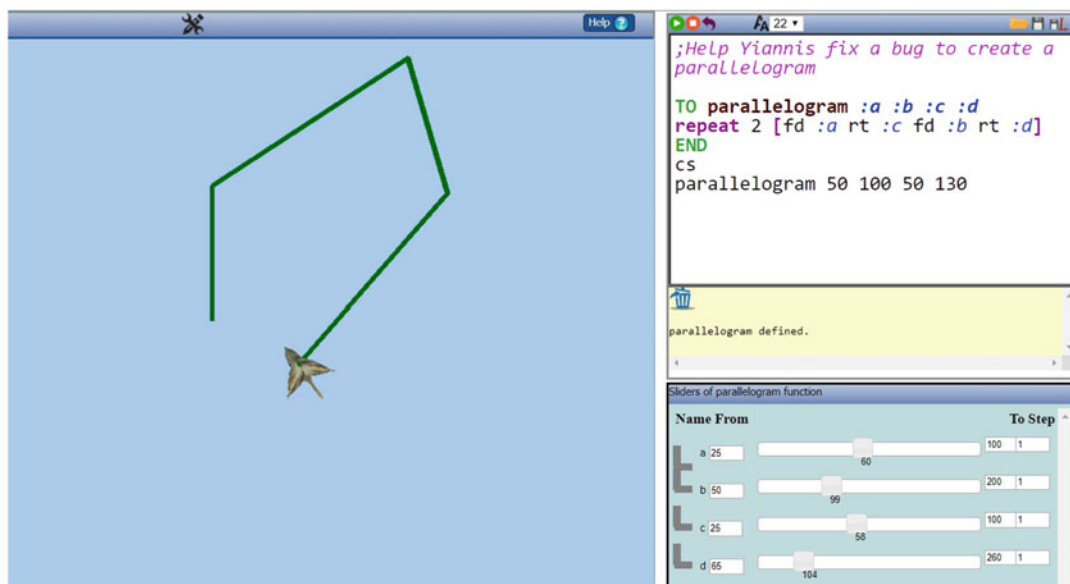
The idea of the microworld associated with Logo Geometry evolved over the years, along with the technological advances of software and hardware. Today, there are a number of online authoring systems for designing, using, and sharing mathematical microworlds. Some of them, like GeoGebra 3.0 (<https://www.geogebra.org/>) and Cabri Géomètre (<https://cabri.com/en/>) (Balacheff and Kaput 1997) environments, provide the learner with a number of visual tools instead of programming, while others integrate programming with computational affordances such as dynamic manipulation (Fig. 1). For example, Machine Lab Turtlesphere 2 (MaLT2; <http://etl.ppp.uoa.gr/malt2>) (Kynigos and Grizioti 2018) is an online environment that combines Logo-

based programming with dynamic manipulation and 3D navigation for the exploration of mathematical concepts. Despite their strong connection with mathematics education, microworlds have also been used in CBL activities for other scientific domains, such as physics, engineering, and history (Healy and Kynigos 2010).

Kynigos (2007), based on the idea of microworlds, coined the term “half-baked microworlds” which refers to “fallible artifacts” pedagogically engineered so as to have one or more “buggy” behaviors built into them. The aim of these “bugs” is to provoke students to fix them in order to improve the original artifact. One characteristic example is the half-baked micro-experiment “Help Yiannis fix a bug” developed in the authoring system MaLT2 (Kynigos and Grizioti 2018). The term micro-experiment refers to a microworld that has a much more focused problem comprising of a set of closed questions and only ending up with an open question leading to investigation. For instance, the micro-experiment of Fig. 2 contains a Logo code that constructs a “broken” parallelogram, and it asks students to inspect the code, identify the bug, and fix it, thus looking deeply into the properties expressed with the buggy code. The concept of micro-experiments was coined by Kynigos and Grizioti (2018) as an approach to reach a larger number of teachers and students in the classroom, attempting to increase the scalability of the MaLT2 environment in the formal educational system.



Computer-Based Learning, Computational Thinking, and Constructionist Approaches, Fig. 1 Mathematical microworlds created in GeoGebra (left) and MaLT2 (right) authoring tools



Computer-Based Learning, Computational Thinking, and Constructionist Approaches, Fig. 2 The micro-experiment “Help Yiannis fix a bug” in the environment MaLT2

Agent-Based Modelling and Simulations

Agent-based modelling is a CBL approach that is usually used for simulating complex phenomena with multiple, interacting digital agents. In such models, the learner specifies the behaviors, interactions, and rules between the agents and observes the emergent outcomes in the system. Agent-based modelling has been used in educational contexts for diverse domains such as biology, mathematics and probability, programming, economics, and urban planning. Today there are a number of agent-based environments that are used for designing models and simulations of scientific or social phenomena.

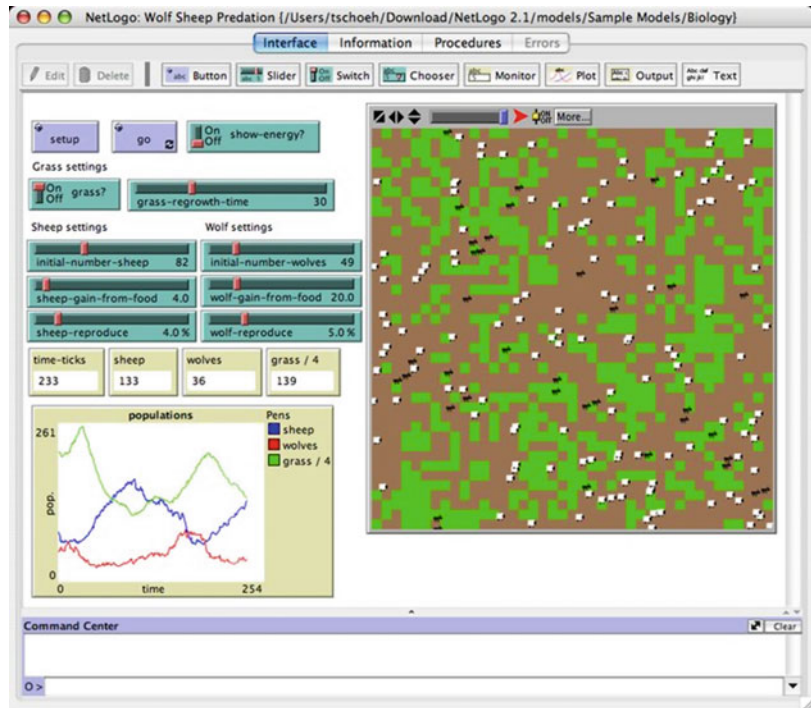
For example, NetLogo is an agent-based modelling environment that is widely used in school contexts (Wilensky and Resnick 1999). Students can control thousands of independent agents, called “turtles,” which they all operate simultaneously (Fig. 3). This enables the exploration of the phenomenon in two levels: (a) in a microlevel, regarding the connections, behaviors, and interactions between the agents, and (b) in a macro-level regarding the patterns and the results that emerge from these interactions in the whole system.

Simulation models developed with NetLogo are based on the idea of “thinking in levels.” The notion of levels focuses on the investigation of how complex phenomena can arise from simple components and simple interactions (Wilensky and Resnick 1999). The agent-based computational representation of otherwise complex phenomena is a form of what Wilensky and Papert (2010) called “restructurations.” They considered restructurations as “reformulations of knowledge disciplines through new representational and communicational forms.” In simulations of NetLogo, the computational objects (agents) replace more traditional representations of a phenomenon (i.e., algebraic). These objects have cognitive, social, and affective properties that make complicated topics accessible and learnable by a much wider and younger population (Wilensky and Papert 2010).

Another example of an agent-based modelling environment is AgentSheets (<http://www.agentsheets.com/>) (Ioannidou et al. 2009). In AgentSheets learners can create agent-based simulations, using its end-user programming language Visual AgenTalk (VAT). They can build rules for the agents’ behavior by combining

Computer-Based Learning, Computational Thinking, and Constructionist Approaches, Fig. 3

A simulation of an ecosystem of wolves and sheep created with NetLogo



conditions and actions from special command palettes. The commands are pre-defined and limited in number which makes the environment easily accessible by people with no previous experience in programming. However, this may also have some limitations regarding the expandability and complexity of the simulations that one can design, lowering the ceiling for the experienced users. AgentSheets has been used in schools mainly as a tool for designing simulation and games in a variety of domains including computer science, environmental design, fine art, robotics, music, history, and biology.

AgentCubes (<https://agentcubesonline.com/>) is another version of AgentSheets that enables the design of three-dimensional (3D) games and simulations (Ioannidou et al. 2009). The additional feature of 3D allows for exploration of more complex phenomena and representations in space, raising the ceiling of the AgentSheets version. The environment includes rich media such as audio and 3D models, a 3D environment with layers and camera controls to switch perspectives. The programming of the game or simulations still follows the rule-based approach, in which the user

combines ready-made commands of VAT language provided in command palettes. AgentCubes has been used in the classroom mainly as a tool for the incremental development of students' information technology (IT) skills and computational thinking.

Logo-Based Coding Environments

Even though programming is by itself a type of computer-based learning, not all programming CBL activities are informed by the constructionist approach. For instance, many programming exercises are closed quizzes and puzzles with only one correct answer and with the "making" element being quite limited. In coding learning environments that implement the principles of constructionism, programming is seen as a means for construction and expression of personal ideas, aiming to lead students to the generation of meaning. Thus, the learning activities are based on exploration, building, and testing, sometimes following a model of gradual engagement with the construction.

The earliest example of a constructionist coding environment was Papert's Logo Geometry

in which students wrote commands in Logo language (forward 100, left 90, etc.) to control a moving “turtle” which drew on a canvas as it moved (Papert 1980). Logo programming has been used in CBL for engaging students not only with programming concepts but also with mathematics, physics, arts, and many other domains.

Today there are a number of Logo-based coding environments used in CBL that are aligned with new technological developments (i.e., online access, 3D graphics, etc.). They are all based on the Logo Geometry philosophy, programming a moving avatar that draws on a canvas, but they usually implement different versions of the original Logo programming language, and sometimes they integrate additional functionalities. For example, Turtle Academy (<https://turtleacademy.com/>) provides a number of online lessons with Logo Geometry that run directly on the browser. In addition, it has a “playground” mode for experimenting freely with Logo programming. The context of the lessons and the graphics of the environment resemble the classic Logo Geometry microworld of Papert.

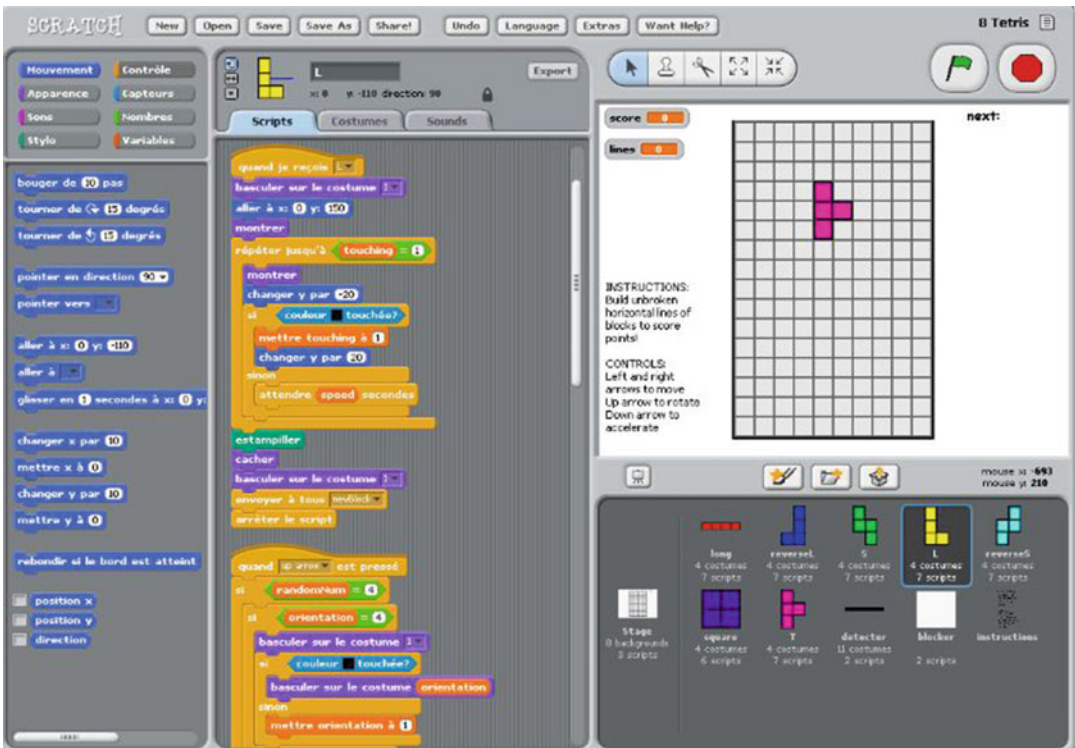
Another Logo-based online environment is MaLT2 (<http://etl.ppp.uoa.gr/malt2/>) (Machine Lab Turtlesphere 2) (Kynigos and Grizioti 2018) developed by the Educational Technology Lab team of NKUA. MaLT2 allows the creation, exploration, and dynamic manipulation of 3D geometrical models with textual programming. MaLT2 implements Logo programming, based on Brian Harvey’s Berkeley Logo, and extends it with the integration of three affordances: (a) 3D drawings, as the avatar moves in three dimensions (x, y, z); (b) dynamic manipulation of any model that has been created by a parametric procedure; and (c) free navigation in the 3D space with a periscopic camera that allows observation of the model from different points of view. MaLT2 has been used in the context of mathematics and computer science education in several schools in Greece and for the development of 240 micro-experiments uploaded in the digital portal of the Greek Ministry of Education (<http://dschool.edu.gr>), one of the most visited sites in the country.

Some constructionist coding environments use visual programming languages instead of

textual programming. Visual programming, like block-based languages, can be beneficial for younger or inexperienced students by decreasing the learning curve of the language and the number of syntax errors that novice programmers usually make.

Scratch (<https://scratch.mit.edu/>) is probably the most popular visual programming environment that is widely used in CBL in the classroom. Scratch was developed by the MIT media laboratory team, and it provides a collection of graphical “programming blocks” which users can snap together to create programs. These blocks are shaped to fit together only in ways that make syntactic sense (Resnick et al. 2009). The Scratch environment and its programming language are based on the idea of Papert’s Logo Geometry; thus every command has visual results on a 2D canvas. Similar to Logo Geometry, the user can program an avatar that moves and draws on the canvas. Apart from that, the environment supports a number of diverse features, like creating and controlling multiple avatars, creating an animation of the same avatar, adding sound and video, and more. The large number of programming options (divided into block categories) allows for the creation of a large variety of projects, from drawings to games and from animations to greeting cards (Fig. 4).

Scratch, apart from being a tool for CBL, also has a large online community in which teachers, researchers, and students create, share, evaluate, and remix Scratch projects on the web. Since the public launch of Scratch in 2007, millions of students around the world have used it to construct their own interactive stories, games, and animations – and share their creations with others. Today, Scratch has been integrated as a suggested coding environment in computer science curricula of many different countries, and it has been translated into more than 70 languages. In addition, a large number of studies have shown its benefits in the development of students’ IT skills, motivation, design skills, and computational thinking skills. However, some researchers have criticized Scratch, and block-based programming in general, for lowering the ceiling of the programming process and having significant limitations



Computer-Based Learning, Computational Thinking, and Constructionist Approaches, Fig. 4 The CBLE of Scratch

compared to text-based programming environments (Grover and Pea 2013). For instance, Scratch does not support the creation of functions, which is a core element of procedural programming. A new environment called “Snap!” that allows the creation of new Scratch Blocks could possibly be a way to address this issue.

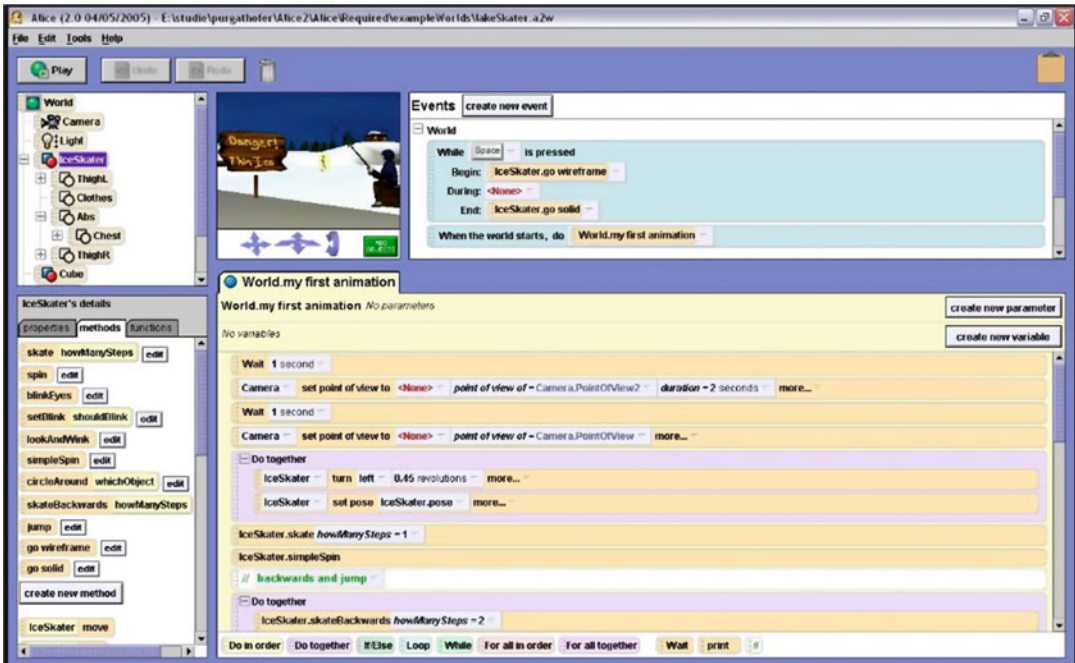
Other online visual programming learning environments that implement Logo Geometry include BeetleBlocks (<http://beetleblocks.com/>), which integrates block-based programming and 3D Logo Geometry, and Pencil Code (<http://pencilcode.net/>) that provides the opportunity to switch between block-based language and JavaScript. However, they have not yet been used as tools for CBL activities in the classroom context.

Game Design Environments

Children today spent a lot of their time playing video or mobile games, so game design activities

can be quite motivating and interesting to them. In game design with computer-based learning activities, students explore ideas about one or more domains by designing a digital game in a learning environment. Constructionist game design environments provide students with powerful tools to build, test, and share their own digital game, giving them the role of both the player and the designer of the game. The CBL environments usually include programming, but they may also integrate additional affordances like a text editor or a graphic designer.

In game design activities, students have to deal with a complex interactive system (the game), the design of which requires system-based thinking and iterative problem-solving (Salen 2007). According to Salen, students as game designers are engaged in a cycle of iterative playtest, evaluation, and modification of the game system. In order to create a functional, meaningful, and attractive game, they get involved with complex



Computer-Based Learning, Computational Thinking, and Constructionist Approaches, Fig. 5 Alice 2.0. CBLE

processes and decisions, such as writing the script, programming the rules, creating the characters, and making artistic and aesthetic choices. During these processes, students usually apply high-order skills and also knowledge from different domains. Thus, game design has been used in the CBL of diverse school subjects such as computer science, physics, engineering, history, and also for multi-disciplinary learning.

One widely used game design platform is Alice (<https://www.alice.org/>), a visual programming environment with 3D interactive graphics, where students can control the behaviors and rules of 3D objects by writing simple scripts. Its visual programming language provides the user with a number of built-in actions that can be used either to program the behavior of objects (e.g., move, turn, roll) or to change the physical nature of an object (e.g., resize, hide, etc.). It also allows users to create new functions, a feature that gives extensibility to the original language and a high ceiling to the tool. The new version of the learning environment (Alice 3) maintains the features of previous ones but adds emphasis on object-oriented

concepts. Since the early 2000s, Alice has been used in several middle schools and high schools, mainly as a CBLE for the subject of computer science. Relative research (Werner et al. 2012) has shown that Alice can be a powerful tool for introducing programming to young students as it allows them to focus on problem-solving skills instead of spending time on syntax errors, compilation errors, and environment set-up problems (Fig. 5).

Gamestar Mechanic (<http://gamestarmechanic.com/>) is another CBL environment for game design that aims to provide young children with “a platform on which they can build technical, technological, artistic, cognitive and social skills suitable for our current and future world” (Salen 2007). In Gamestar activities, students can have different roles. They can be players, designers, reviewers, and modders of games. They can also share their games in the online community of Gamestar and comment on each other’s games. Gamestar also provides a number of resources for teachers to implement in their classrooms, including single-session activities and long-term

curriculum. Gamestar has been used for teaching concepts from different domains including game design, science, arts, and science, technology, engineering, and mathematics (STEM) education.

In studies with Gamestar Mechanic (Salen 2007), researchers applied the method of game modification to introduce students to the elements of the game and the game principles. They designed small challenges of increasing difficulty to scaffold students' engagement through progressive modifications. The studies showed that game design increased students' motivation to participate in computer programming and their interest remained high throughout the activity. In addition, their studies suggest that game design can help students cultivate skills such as creative problem-solving, writing and storytelling, IT skills, and critical thinking.

Integrated Affordances

An important element in CBL is the affordances of the learning environment and the way that students use and combine them to construct knowledge. In the context of a digital learning environment, affordances are considered as the opportunities that the environment offers to the learning process by enabling a number of actions to the student. The way that students would perceive and utilize the affordances depends on their existing knowledge structures and experiences, and as their knowledge evolves so may their perceptions of the environment's affordances. In constructionist learning environments, the affordances are formed by the available tools and functionalities for construction but also by the behaviors and interpretations that students may assign to the tools while they use them. Thus, the type of integrated tools in a learning environment and the way that they are connected with each other by design can play an important role in CBL.

Aiming to extend the idea of scaffolding, Noss and Hoyles (1996) introduced the term "webbing" to describe "a structure that learners can draw upon and reconstruct for support in ways that they choose as appropriate for their struggle to construct meaning." The webbing notion builds

on the perception that learning is the construction of a web of connections of scientific ideas including connections between classes of problems, between mathematical objects and relationships, etc. (Noss and Hoyles 1996). Each student constructs personal intellectual structures that form his/her network of connections by utilizing what he/she chooses as appropriate and supportive from the pedagogical setting at the current time of learning. In that context, they focus on the flexibility of the computational learning environment and on the affordances that it provides to the learners so that they can gradually build and use such webbing structures within the environment. More recently, Weintrop and Wilensky (2014) described webbing as "a way to study the learning process as it emerges through the use of the affordances of the digital environment in concert."

Utilizing the construct of webbing, Weintrop and Wilensky (2014) designed a constructionist video game called "RoboBuilder." It is a program-to-play video game that "challenges players to design and implement strategies to make their on-screen robot defeat a series of progressively more challenging opponents in one-on-one battle" (Weintrop and Wilensky 2014). The environment integrates two distinct but connected components: a programming environment with block-based programming and an animated robot battleground. In their studies with RoboBuilder, Weintrop and Wilensky (2014) investigated how the connected features of the game environment contribute to a player's developing understanding of programming concepts.

Kynigos and Grizioti (2018) use the term "integrated constructionist designs" to describe enriched computational environments which didactically combine programming with other affordances. The affordances are carefully chosen to make complex scientific concepts accessible to students through multiple representations and at the same time support the construction of personal artifacts. An example of such design is ChoiCo (Choices with Consequences) (<http://etl.ppp.uoa.gr/choico>), an online authoring environment that allows the design and play of choice-



Computer-Based Learning, Computational Thinking, and Constructionist Approaches, Fig. 6 ChoiCo learning environment in Design Mode

driven simulation games that usually deal with complex socio-scientific issues. In ChoiCo games, the player revolves around different map-based settings and makes selections (these can be items, buildings, actions, etc.) that have specific consequences to a number of game parameters (i.e., Money, Health, Fun, etc.). The aim is to remain in the game by keeping the values of the parameters between specific red lines (limits). All the game elements can be designed or modified in the “Design Mode” of the environment (Fig. 6). ChoiCo integrates three affordances for the design of its games: (a) a map-based editor for constructing the game scene; (b) a modifiable database for specifying the consequences of the game items (choices); and (c) block-based programming for constructing the rules and the feedback of the game. The integration of these affordances provides access to complex scientific concepts such as randomness, patterns of behavior, event handling, data management, abstraction, etc. In addition, the genre of ChoiCo games (choice-driven simulations) combined with these three affordances allows for exploration, discussion, and expression of ideas related to socio-scientific issues with no profound solution. So far, there are a number of diverse games designed with ChoiCo for CBL purposes including games for environmental education, mathematics, computational thinking, ancient Greek, healthy diet, and ethics.

Computational Thinking and Constructionist CBL Approaches

Computational thinking refers to the mental process of understanding and solving problems through the efficient processing of information (Lee et al. 2011) and the construction of automated models, systems, and representations (Wing 2006; Lee et al. 2011; Grover and Pea 2013). For thinking computationally, one should develop a set of skills, strategies, and behaviors that come from computer science, but they can also be applied in other problem-solving contexts and situations. The set of skills that constitute computational thinking include among others decomposition, pattern recognition, generalization, abstraction, algorithm building, debugging and error detection, and information and data processing (Brennan and Resnick 2012; Grover and Pea 2013).

Despite the fact that computational thinking is considered one of the twenty-first-century competencies that students should develop, there is still no clear picture on how CBL should be designed in order to help students acquire and develop CT skills. Skills and abilities, in contrast to specific knowledge, are more difficult to be developed with traditional designs (i.e., instructionist or behaviorist designs) and to be assessed with closed exercises, quizzes, and tests. People usually acquire skills through experience and active

engagement in situations, and they should be able to apply and practice these skills in other contexts. For the development of CT, it is important to provide students with rich computational environments with low threshold and high ceiling that would allow them to transfer skills and knowledge in diverse situations (Grover and Pea 2013; Lee et al. 2011). The constructionism paradigm could inform such designs of educational environments in which students would develop CT skills by constructing and sharing personally meaningful artifacts with programming and other affordances.

However, in contrast to behaviorist approaches and guided quizzes, constructionist activities may require a great deal of time and effort from the students to familiarize with the environment, until they could actually apply, let alone develop, such skills. One popular approach that is used to overcome this problem is to provide students with scaffolds for building their artifacts. Students do not start from scratch to explore programming and create a new artifact, but they follow small steps of engagement. Many studies use the three-stage model of engagement “Use-Modify-Create” coined by Lee et al. (2011) for achieving a progressive engagement of young students in CT skills within rich computational environments. According to the model, children are gradually engaged with the affordances of the environment, transforming from users to creators and tackling with higher design challenges as their skills and knowledge increase (Lee et al. 2011). This model has been used for the design of CBL activities that focus on the development of students’ computational thinking, including game design, simulations (Lee et al. 2011), and game modding (Grizioti and Kynigos 2018).

A similar method to the above model is “remixing.” The Scratch community coined this approach as a way for enabling students’ progressive engagement with Scratch programming and with computational thinking skills. It refers to the process of finding ideas and code from existing Scratch projects and building upon them. This gives students the potential of creating much more complex artifacts than they could have created on their own (Brennan and Resnick

2012). Depending on the depth of remixing, it can require a high degree of sophistication and CT skills (Kafai et al. 2014). Recent studies on computational thinking have used constructionist digital environments, including Scratch, to investigate how students apply and develop CT skills while they construct, modify, or remix artifacts with them (Brennan and Resnick 2012; Grover 2017; Kynigos and Grizioti 2018; Werner et al. 2012).

ScratchMath is a large-scale research project that aimed to build mathematical knowledge and computational thinking skills through programming in Scratch during a 2-year intervention in a class context for students aged 9–11 years. In the first year, the intervention focused on computational thinking with an implicit mathematical component, while in the second year, it emphasized the exploration of key mathematical concepts using programming tools. According to the preliminary results of their study, their framework was “flexible enough for teachers to adapt to their own teaching style and experience as well as the needs of their pupils to communicate key computational and mathematical ideas in different ways whilst staying true to the goal of the learning activity” (Benton et al. 2017).

The Alice environment has also been used for studying the benefits of game design in the context of computational thinking development. One example is the iGame after-school in which students programmed their own digital games with Alice 2.2 and Storytelling Alice (Werner et al. 2012). The researchers studied students’ performance in the “Fairy Assessment,” an Alice program designed to analyze two CT skills: algorithmic thinking and effective use of abstraction and modelling. The assessment included three tasks with Alice, and it was designed according to the model “Use-Modify-Create” described before. Their results showed that students had increased motivation in programming after the program, but their performances between the tasks varied. The majority of the students had better performance in the task related to comprehension and less to that related to design. Another interesting finding is the increased CT

performance and scores of students who worked using pair programming in comparison to those who programmed alone.

Grizioti and Kynigos (2018) investigated how students apply and develop computational thinking skills when they progressively modified a simulation game. They designed a game modding activity in the CBL environment “ChoiCo” according to the model “Use-Modify-Create.” In the study, middle-school students, divided into groups of two, first played a “half-baked” game, then they improved it by fixing its bugs, and finally they created their own version of the game (mod) which they also shared with their classroom. Their study showed that students used the skills of pattern recognition, algorithmic building, and abstraction for recognizing and modifying the rules, items, and behaviors of the initial game. They also found an increasing complexity in the patterns and rules that students implemented from the beginning to the end of the activity.

Finally, there are a number of resources available for teachers and researchers, which describe methods for developing and evaluating CT with digital technologies in the classroom. For instance, a team from Harvard University in collaboration with Mitchel Resnick created a website where they provide examples, assessment methods, and support on using Scratch in the classroom, especially for the development of CT (<http://scratched.gse.harvard.edu/ct/>). In addition, Brennan and Resnick (2012) developed a computational thinking framework that emerged from their studies with Scratch and describes computational concepts, practices, and perspectives as well as assessment methods to evaluate them.

Challenges and the Near Future of CBL

For over two decades, constructionist epistemology has held a central role in computer-based learning. Especially now, with digital technologies and programming becoming an integral part of a new kind of computational literacy, there is a need for CBL designs that will promote creativity,

communication, and construction. The level of interactivity as well as the high freedom in construction and self-expression of constructionist CBLEs can make constructionism a strong pedagogical framework for the design of new CBL approaches that aim to cultivate twenty-first century skills including computational thinking and deeper learning. However, there are still some challenges that constructionist CBL environments should overcome.

Adaptability is an important element of CBL and involves the personalization of the learning process and the provision of feedback according to the needs of the learner. One question is how we can individualize a constructionist activity without restricting its open and exploratory character. How can we design a constructionist environment that would provide appropriate feedback to the learner without being strictly guided?

The design of CBLEs in which students would practice and cultivate computational thinking and other twenty-first century skills is also a challenge for the future of computer-based learning. There have been some first steps in designing constructionist environments and applying them in classroom contexts in order to support students to acquire such skills, like the examples we described in the previous section. However, there is still a need for assessment methods, curriculum designs, resources, and pedagogical frameworks for computational thinking to be developed.

The affordances of a CBLE can play an important role in learners’ engagement with the environment and in the knowledge and skills they would construct through this interaction. The challenge in this context is what kind of affordances should be integrated into a learning environment and how they should be combined together in order to support the generation of meaning and the construction of knowledge. For instance, should we focus more on block-based and visual programming or should we emphasize finding new ways to integrate textual programming with other affordances? This is an ongoing challenge, since each new affordance providing the potential for expressivity poses a need to study

the ways in which it may be put to use (Kynigos and Grizioti 2018).

Finally, scalability is always a challenge for constructionist approaches as there are still significant issues when it comes to their implementation in the school context. The implementation of such designs in the classroom usually requires time and effort from the teachers in order adapt their teaching. So, how can we smoothly integrate constructionist designs in a large number of schools, i.e., on a national scale? One approach that recently achieved a good level of scalability regarding both the number of schools and the duration in school years was the ScratchMath project described before. Another was the approach of micro-experiments, focused questions in constructionist environments that led to investigations, which are integrated into a digital portal accessed by hundreds of schools (Kynigos and Grizioti 2018). Similar approaches may open the way for constructionist CBL to be applied at larger scale.

Conclusion

Computer-based learning (CBL) has been used for almost 50 years in schools as a method to support the process of learning. CBL and the pedagogical frameworks that underpin its designs have evolved through time according to the technological advances of each era. The initial behaviorist and computer-centered approach of drill-and-practice technology was succeeded by exploratory systems and simulations that focused on discovery learning and by programmable, constructionist environments that emphasized the socio-constructionist perception of learning. According to different studies, computer-based learning can, in some cases, have positive effects on students' understanding and meaning generation in several domains. However, there are a number of challenges and factors that should be taken into consideration with respect to the pedagogical design of both the digital learning environment and the activities of CBL, in order to meet the needs of the twenty-first-century students.

Cross-References

- [Computational Thinking](#)
- [Computer-Assisted Learning](#)
- [Teaching with LOGO Philosophy](#)
- [Technologies in Mathematics Education](#)

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Computer-Based Management Information Systems

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Computer-Based Training

- [Distance Learning](#)

Computer-Based Training and School ICT Adoption, A Sociocultural Perspective

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Synonyms

[Case study research](#); [Community of practice](#); [Computer based training](#); [Educational technology](#); [Innovation](#); [Interactive whiteboards](#); [School culture](#); [School leadership](#); [Socio-cultural theory](#)

Introduction

Various terms and concepts are used to describe how computers and technology generally are employed in schools and how they support

the training of teachers. Since its inception, educational computing and its associated terms have been shaped by both the technology itself as well as by prevailing teaching and learning paradigms and their associated psychological and pedagogical underpinnings. In its 60-year history, educational computing has evolved through three key phases, each lasting approximately 20 years. This evolution has not occurred in isolation, but rather has been a complex continuum involving a confluence of concurrent developments in technology, psychology, and pedagogy.

The first phase which ran from the early 1960s to the early 1980s ushered in the era of the teaching machine, where the computer was seen primarily as a surrogate or replacement teacher. Terms such as “Programmed Instruction,” “Intelligent Tutoring Systems,” and “CBT/CAI” (computer-based training/computer-assisted instruction) were invariably used to describe this new educational development where content was delivered to students in byte-sized chunks, followed by knowledge tests delivered by large expensive mainframe computers. However, the effectiveness of such systems were limited due to: costs which put them beyond the reach of most schools; technical constraints in terms of computer memory capacity; computational speed; portability; and, most important of all, the didactic nature of the programs themselves. In the context of the times, this didacticism is understandable given that teaching was primarily seen as an instructional or transmission-like activity based on behavioral psychology theory as popularized by B.F. Skinner (1904–1990).

The second phase, which was inspired by the invention of the microprocessor, commenced in the early 1980s. During this period, new developments in hardware and software technologies ushered in the era of the personal computer (PC) or desktop computer. As PCs became much more affordable, much smaller and more powerful, schools gradually began to purchase multiple devices placing them mainly in dedicated computer rooms for use by individual classes using a timetabled system. The lexicon of terms associated with this era such as “drill and practice,” “computer-based learning,” “multimedia

learning,” “interactive learning,” “computer supported cooperative learning” (CSCL), “micro worlds,” “hypermedia,” etc. gives an insight into the PCs evolving technical capabilities as well as the emergence of more modern learning theories and methods inspired by newer developments in psychology. While initially new courseware developed and delivered using CD-ROMs (Computer Disks Read Only Memory) on personal computers followed a similar instructional or “drill and practice” format to that of its mainframe predecessor, innovative practitioners and educational researchers inspired by cognitive and developmental psychology as well as constructivist learning theory began to push out the boundaries of educational computer use. In particular, the notion of a computer as a tool to learn with, rather than as a tool to learn from, gained prominence in research discourse; for policy makers and innovative practitioners, this meant that “the way the computer ought to be used in schools changed from a traditional understanding of technology-as-teacher to technology-as-a-partner in the learning process” (Jonassen et al. 1999).

The third and current phase, which began in the early years of the new millennium, was inspired by the invention of the internet, the World Wide Web and web browser technology in the mid-1990s. The communications and information revolution that the internet instigated greatly expanded the role and possibilities for school computing. It was now possible to provide online access to learning resources anywhere, anytime and utilize the web’s communications capabilities to support cooperative and collaborative learning as well as student dialogue, interaction, classroom exchange, and expert mentoring. A plethora of new terms emerged to capture technology’s enhanced educational possibilities such as “e-learning,” “online learning,” “virtual learning environments” (VLE), “blended learning,” “learning 2.0,” “mobile learning” (M-Learning), and “MOOCS” (massive open online courses), among others. In particular, the web’s communications’ features appeared to better accommodate the more social and cultural aspects of human development and learning advocated by psychologists such as Lev Vygotsky

(1986) and Jerome Bruner (1986). This led to a move away from the more structured and individualistic approaches to learning popularized by drill and practice software to utilizing more web-based communication technologies such as wikis, blogs, social media, conferencing tools, and mobile devices, which when appropriately deployed, had the potential to create richer, more reflective, and more active and authentic learning environments.

During this period, the devices used to facilitate learning changed, with desktops replaced by laptops, which in turn were replaced by smaller and more mobile devices such as chrome books, tablets, iPods, and even students' own mobile telephones in schools favoring a BYOD (bring your own device) system. This period also witnessed the introduction of Interactive Whiteboards (IWB), particularly in primary schools. These large interactive screens with instant access to the World Wide Web and other learning materials and resources replaced traditional chalkboards, whiteboards, and overhead projectors in classrooms. In many schools, the introduction of IWB technology and mobile learning devices, particularly where both technologies were utilized, meant the dedicated computer room as the main source of computing access declined, as varied Internet connected devices could now be deployed in classrooms and utilized throughout the school.

Given the ever-changing nature of school computing, devices, and associated methodologies, it can be difficult to define exactly what is meant by computer-based training (CBT). Traditionally the term was associated with use of computers to deliver training and teaching in the form of expertly designed courseware and tests without the physical presence of a human teacher or trainer during learning or testing. However, as technology evolved, alongside an increased understanding of the pedagogical limitations of using computers as surrogate teachers, especially in formal education, CBT became more of a catch-all phrase to describe the use of computers in education. Therefore, for the purpose of clarity in this entry, computer-based training is understood as a broad-based term that

encompasses any use of a computer for the purpose of assisting training, teaching, or learning in schools including the training of teachers.

Despite many exciting developments in educational technology and computers since the 1960s, and the increased, often (near) ubiquitous availability of devices, school computing has not had the impact expected of it, with ICT adoption and integration consistently falling short of expectations. From Cuban (1993) to Selwyn (2010a), numerous researchers worldwide have noted that the realities of computer use in schools fall short of the rhetoric, effectively meaning that despite the uptake of technology in education, ICT has not had a transformative effect on teaching and learning (Ala-Mutka et al. 2008) and has failed to achieve its full potential (Kampylis et al. 2012). While many research studies have pointed to individual factors such as poor infrastructure, inadequate teacher CPD (continuous professional development), first and second order barriers, technocentrism, policy deficits, and poor curriculum fit as the sources of the problem, others have adopted a more holistic approach by utilizing a sociocultural theoretical lens to focus on the wider context of schools as organizations and the interaction between technology, teachers, and school culture. Within social-cultural theory, culture is seen as a dynamic interaction between the individual and organizational environmental contexts (Rogoff 1995). Therefore, in the study of this interaction, socioculturalists take into account how cultural, institutional, individual, and social factors influence human behavior, and in the process unveil how deep, often subconscious, sociocultural practices, such as beliefs, values, norms, customs, and attitudes, affect how people think and act. In this respect, it can be argued that a full understanding of the integration and adoption of technology in schools must include the effects of social and cultural forces operating at an organizational and societal level.

To illustrate how this plays out in practice, the remainder of this entry will present the case of a multi-site educational technology project on Interactive Whiteboards (IWB) that took place over a 2-year period in Ireland utilizing a sociocultural perspective to analyze the findings.

IWB Project Background and Context

The IWB pilot project commenced in the second decade of the new millennium as part of an EU (European Union) project designed to facilitate the transfer of “good practice” in the delivery of IWB training in Ireland. Its core aim was to support the continuous professional development (CPD) of teachers and trainers working in the vocational educational and training sector (VET) on the use of Interactive Whiteboards. To achieve this aim, Irish VET teachers and tutors were provided with a comprehensive training program involving seminars and workshops as well as a range of print-based CPD materials and a series of online instructional videos covering all aspects of IWB use catering for both novice and advanced users. An online Community of Practice (COP) website was also provided.

A total of seven Irish VET schools (officially referred to as VET centers) participated in the pilot. All were involved in teaching adults, at-risk youth, and second chance education learners (i.e., both young and older adults who, having left school early without obtaining formal qualifications, had now returned back to education). Therefore, the aggregate age span of their students ranged from late teens to early 60s. While overall responsibility for the project’s implementation in Ireland lay with the Regional Coordinating School Authority, a project champion working in each school center was responsible for the day-to-day implementation of the project at local school level. Each project champion was a school-based teacher who was selected to become a champion following an open recruitment process. All were chosen based on their ICT competency (not necessarily with IWBs, although some had this experience), their ability to act as role models for others in using technology, as well as interest in and enthusiasm for the project. Notably, most project champions were younger teachers with less than 10 years’ teaching experience. The project champions were the first group of teachers to benefit from training on IWBs devised by the EU project partners before going on to assist as trainers on

courses, workshops, and seminars organized for participating schools.

Research on the IWB project took place over a 3-month period towards the end of the project’s final year. The research was conducted using a series of case studies involving semi-structured interviews as the main data collection tool supplemented by artefactual analysis of the community of practice and other project materials. More than half of the schools participated in the research. Interviewees comprised three groups involving: (a) Teachers/Tutors; (b) Center Coordinators (i.e., School Principals); and (c) Project Champions. For the most part, Teachers/Tutors participated in Focus Group Interviews, consisting of 3–5 participants, while School Principals and Project Champions were individually interviewed. A total of 32 participants ($n = 32$) took part. While the research aimed to capture a number of project outcomes, the most important findings to emerge from an analysis of the research data, and the most relevant from this entry’s perspective, were related to:

- Teachers’ use and integration of IWBs
- The role of the Project Champions
- The effectiveness of the online Community of Practice concept and platform for supporting collaboration and sharing of resources and expertise in relation to IWB CPD

Teachers’ Use and Integration of IWBs

The widespread introduction of IWB technology in schools “opened up the possibility of integrating technology more fully into teaching and learning in every curriculum subject” (Moss and Jewitt 2010). Since their adoption by schools from the early 2000s onwards, IWBs have become a permanent fixture in many classrooms. Research evidence from many countries, but particularly the United Kingdom (UK), most of which was gathered between 2000 and 2010, revealed that teachers used and integrated the devices to support classroom learning. Once initial learning curve hurdles were overcome, teachers for the

most part embraced the technology, utilizing its many features such as interactivity, enhanced presentation capabilities, drawing and annotation tools such as infinite cloner, and drag, drop, and reveal among others. However, the technology was not without its detractors, with some researchers cautioning that teacher enthusiasm for IWBs was due in no small way to the manner in which it fitted into traditional classroom teaching practices (Somekh et al. 2007; Dudeney 2006), thereby reinforcing didacticism and whole class teaching (Gray et al. 2007), rather than transforming teaching methodologies and existing ways of working (Moss et al. 2007; Coghill 2002). In this respect, the device could be viewed largely as a teaching tool more suited to teacher use rather than a learning tool for use by students. Nonetheless, numerous studies from the first decade of IWB use in schools as well as more recent studies (Passey 2016) indicated that the device, especially when used as a form of “digital hub,” (Moss et al. 2007) helped teachers to integrate and make better use of ICT in classrooms.

A key objective of this research study was to capture the extent to which and in what way VET teachers were using IWBs to support teaching and learning. Having previously conducted research on the first IWB project in Irish schools nearly a decade earlier, which illustrated how IWBs had positively influenced ICT integration (Judge 2010), a similar outcome was expected here. This turned out not to be the case with 14 (66%) of 21 class teachers interviewed revealing that they had not used the IWB since participating in training. Furthermore, of the other seven teachers who had used the IWB, only three described themselves as “regular IWB users” with the remaining four using the term “occasional IWB users” to describe their level of use.

This relatively low number of project participants claiming to use IWBs regularly was clearly unexpected and disappointing. Fortunately, the research interview process afforded space and time to explore the issue more fully and in greater depth with participants. A subsequent systematic analysis of the research interview data revealed that a number of factors were responsible for

participants’ nonengagement, the most important of which were:

- Problems with initial training
- Time and timing issues
- Staff contractual arrangements and insufficient resources

Initial Training

Research feedback from participants indicated that the majority of teachers were disappointed with the initial training courses and workshops as they felt they had neither met their needs nor delivered on what was promised. Most teachers believed that they were too theoretical, with no time, or very little time, allocated for practice. It was felt that too much course time was devoted to explaining the academic rationale behind IWB usage leading to an over-emphasis on “show and tell” rather than “learning by doing.” A number of teachers were also quite suspicious about the motives behind the training course, believing that they were largely a promotional exercise by SmartBoard, the IWB board manufacturers themselves, to promote their product. Although this was clearly not the case, as the manufacturers were not involved in any way, it is interesting that this is the impression that came across in some quarters and it was clearly off-putting for those teachers. In the aftermath of the initial training, teachers felt that they neither had the skill set nor the competency to commence using the IWB in their classrooms. As one Project Champion articulated:

I think here the initial training went reasonably well but my feeling was that some people were quite negative about the lecture style format. So I feel in terms of both presentations there was a tendency to be too academic about it and that really didn't go down well, even with people who had a strong background in educational theory. They felt they were being talked down to and they just felt alienated by it.

In a similar vein, another teacher commented:

I signed up for it originally because I had never used whiteboards before and my whole idea was that through the training I will get more hands on and get experience on how to work it so that I might

be able to use it with my class. But I ended up dropping out of it because it was too theory based, more go off and do your homework type thing. Because I wasn't getting the opportunity to do the hands on work, I felt it wasn't hitting what I needed, so I felt this is not what I signed up for; this is all just paper exercises, no hands on, and none of us needed any more paperwork.

Unfortunately, the disappointment in the content and direction of initial training had serious implications for the project's development, as the majority of teachers immediately lost interest in the project. As one Principal noted, *"while the majority of staff attended initial training only two staff members pursued it to the end which is a pretty high rate of attrition."* This is despite the fact that although the local Irish project team tried their best to rectify the initial training issues by designing and delivering a more practical hands-on bootcamp-style training workshop in the project's second year, teachers did not re-engage. For those who did attend, the boot camp model was very favorably received and strongly praised and endorsed by the teachers who participated:

The boot camp was great. I would have liked the boot camp to come first because it was more experiential learning and I think that even people who were new to the whiteboard would have got more of an opportunity in a fun kind of way to begin working with it.

In hindsight, it is clear to see that initial training which was fundamentally "top-down" in nature was not fit for purpose; instead, as Schmidt and Schimmack (2010) demonstrated in their research on IWB training for teachers in Germany, a "bottom-up" model involving teachers themselves in training design is the desired and far more effective approach. Furthermore, as other research has illustrated (Pearson et al. 2004; Somekh et al. 2007) continuous and on-going CPD, preferably conducted on site rather than a single training event usually conducted at the beginning of an innovation, is far more effective in promoting successful IWB use.

In fairness to the project leaders, while face-to-face training workshops and seminars represented the main vehicle through which teacher training was provided, additional materials to support ongoing CPD training such as training manuals,

instructional videos, and an online community of practice site were also provided. However, research feedback revealed that most teachers did not use or consult these resources over the course of the project. Lack of time and lack of interest were cited as the main reasons for not using these resources. The problematic issue of time and how it affected overall project engagement was singled out by most participants and this will be discussed in greater detail in the next section.

Time and Timing Issues

Time was one of the biggest impediments to IWB usage cited by virtually all interviewees. The time barriers appeared to have a number of dimensions which could be classified as "Bad timing," "Lack of time to practice" and "Lack of time to develop resources." This is not unusual. As Selwyn (2011) reminds us, "time is often highlighted as an overriding concern in studies of teachers' work." This is especially true when it comes to ICT, where teachers frequently identify lack of time as a barrier to ICT adoption, as noted by Judge (2007) in her ethnographic research study on the Wired for Learning Project in Ireland and earlier large-scale quantitative studies conducted in the United States of America (USA) by the Office of Technology Integration (1995) and Quality Education Data Inc. (1995, as cited in Su (2009).

There was a general consensus among all interviewees that the IWB Vet project timing was unfortunate, as it was introduced at a time when the entire VET curriculum was undergoing a major overhaul nationally. This meant that teachers were busy investing all their time and energy in developing and delivering new modules or revamping existing modules, which seriously impacted the amount of time they could devote to the project. This was a source of frustration to some teachers who could clearly see the potential benefits of using IWBs in class but felt they had to prioritize the development of teaching materials for the new curriculum above the IWB project. According to one Principal, this was perfectly understandable as *"teaching has to come first because that is what's valued"* whereas the IWB

project was seen as a temporary fad – “*something that would come in and go out again.*” The loaded nature of this comment should not go unnoticed, as it seems to suggest that Larry Cuban (1986, 1993) was right when he argued that technology has failed to affect schools due to dominant cultural beliefs that permeate both schools and society, which sees teaching as telling and knowledge as a subject matter to be taught by teachers via traditional materials such as books.

Many teachers reported that they did not use the IWB in the aftermath of training; due to the newness of the device, they felt they needed time to practice on it before feeling sufficiently confident to use it in front of the students. Although the software could be loaded onto their laptops for them to practice on in private, and many availed of this facility, teachers reported that experientially this was not the same as actually using the IWB itself. Therefore, despite having the opportunity to experiment with the software on their laptops away from the gaze of students, they still did not feel confident going into class and using the IWB in a live classroom situation.

In addition, many teachers argued that preparing resources was very time consuming, as research elsewhere has also found (Glover and Miller 2001; Lai 2010), and expressed disappointment about how much effort was required to produce even the smallest learning resource. This constraint was best summed up by one teacher who said that it had taken her 4–5 h to create a resource for a task which only took 90 s of class time for a student to complete. Given this ratio, teachers felt that the gap between the end product (resource output) and the level of investment required (teacher input) was too great. There appeared to be little appreciation for the fact that having created a digital resource it would be permanently available for use, re-use, and modification in years to come or that as teachers developed more expertise with IWB technology, resource creation time would also reduce.

The issue of time was further compounded by the fact that very few teachers had permanent access to an IWB in their classrooms. As only a small number of rooms in each center were

equipped with an IWB, teachers had to book these rooms in advance in order to practice using the technology or deliver an IWB-prepared lesson to students. This was a serious problem, which acted as a major impediment to usage post training. This is in line with research evidence from elsewhere (Pearson et al. 2004; Somekh et al. 2007), which argues that teachers are more likely to use and make best use of an IWB when they are permanently available in their classrooms, whereas, as Haldane (2008) points out, fragmented access to the technology negatively affects both teacher competence with and motivation to fully use and exploit the IWB’s capabilities to prepare and deliver lessons.

Staff Contractual Arrangements

A further complication with regard to time required for up-skilling related to the nature of employment in the VET sector, as many teachers are part-time workers, some working as infrequently as 3 h per week, unlike full-time staff who have a teaching allocation of 22 h per week. Part-time teachers are paid on the basis of student contact time only, which means that there is no real incentive to become involved in training or undertake further professional development. This means that involvement in professional development and training is largely dependent on the goodwill and intrinsic motivation of the individual teacher.

Some teachers expressed strong objections to participating in professional development activities for which there was no additional remuneration; some teachers, although expressing willingness to up-skill at their own “time expense,” found themselves unable to do so due to childcare and caring commitments for loved ones which were too difficult to reorganize. There were also significant out-of-pocket expense implications for covering childminders and professional carers for extra hours worked to cover their involvement in training.

This posed a problem for project champions particularly as they felt they could not expect hourly paid workers to get involved in IWB training when they were not being compensated for the extra time required to upskill. Even teachers who

had full-time teaching contracts experienced difficulties finding time to develop their IWB skills, especially when there was limited access to IWBs in their school or training center.

All of these factors encompassing initial training difficulties, time, and timing, as well as staff contractual hours, meant that the Project Champions located in each school faced an uphill battle when trying to encourage staff to use IWBs to support teaching and learning. The somewhat problematic and challenging nature of their role will be discussed more fully in the next section.

The Project Champions

From the outset, the project identified peer tutoring and the role of project champions in facilitating this as central to the project's modus operandi. It was envisaged that the project champions, located in each of the participating centers, would act as coaches and tutors to other teachers in the project. Furthermore, the project champions were seen as a conduit through which a community of practice focused on sharing knowledge and expertise in relation to IWB pedagogy and peer tutoring among teachers could emerge. In line with the philosophy underlying peer tutoring and collaborative best practice, it was deemed important that the champions should be seen by their peers as facilitators rather than as IWB experts.

It was envisaged that the role the Champions would play on site in their own training centers and schools would be most important for the success of the peer tutoring and community of practice model that lay at the heart of the IWB project. Feedback on their function was very positive, with both fellow teachers and school principals describing them as "enthusiastic," "supportive," "knowledgeable," "empathetic," "willing," and "available." The small number of teachers who availed of their services found their support and encouragement invaluable, particularly as it helped to bridge that confidence gap which often arises between training and actual implementation.

From the perspective of School Principals, the provision of one-on-one training and on-site

mentoring by the Champions was essential in terms of helping to maintain overall project momentum through "*handholding some of our teachers who are very needy*" and "*making sure we were kept up to date with the whole project.*" However, despite the high praise from their peers and principals, the Project Champions themselves were more circumspect about their role and achievements and most expressed disappointment at the level of commitment to the project from their colleagues. In reality, most Champions found that few teachers contacted them for help and support even though they did their best to continually remind colleagues of their availability through regular emailing and other means.

Although project buy-in was clearly an issue in some quarters, other factors such as logistical difficulties in terms of peoples' scheduled teaching hours also played a part in frustrating Champions' efforts to support teachers in the way they would have liked. Some champions taught in more than one school center so, therefore, they were not permanently available in one location; most Champions were teachers with significant teaching contracts and therefore were not always free and available, especially to teachers who only came into school to teach their contracted 3–4 h a week and were then gone. This was a source of frustration both for them and for those who needed their help.

Project Champions also expressed concerns about the level of IWB training that they themselves had received. When they applied for the roles, they had understood that they would receive a lot more training with IWB technology before being required to train others. The reality, however, was somewhat different, and consequently they found themselves only one step ahead of those they were expected to train. For most, this was an uncomfortable space, leading directly to the resignation of one Champion, who felt he could not really describe himself as a "Champion," because he did not know enough about the technology.

But, perhaps more importantly, the Champions' role was also constrained by their position and sphere of influence within their organizations. It was noticeable that most Champions

were much younger than many other participants interviewed. Furthermore, they found themselves in the unenviable position of being responsible for driving a project in their local school centers without having any real authority over whether people participated or not. In this respect, they operated at the whim of other people's good will, which was less than ideal situation, particularly when difficulties arose along the way, such as the initial dissatisfaction with the early training course, for example.

Fundamentally, this was largely an organizational management and leadership issue which could have been avoided if the School Principals had taken a more proactive approach to the project's development and the staff engagement challenges their Champions faced. Instead, School Principals tended to take a hands-off approach with one Principal saying: *"from my point of view it was great having the champion here because it meant the staff didn't have to come to me for help"* and another noting: *"it's not that our staff didn't buy into the project, they just didn't buy into the extra work that it involved."* Such comments tell their own story. As anyone ever involved in any school innovation initiative knows, every new project, particularly technology-related projects, requires extra work and commitment from staff, above and beyond normal work hours. Securing people's commitment to these extra work hours is fundamentally a management and leadership issue, which in terms of the implementation of the IWB project was not adequately addressed. Failure to do so left the Project Champions in a difficult position when it came to galvanizing those around them to devote extra time and energy to becoming IWB competent.

Obviously, every new project and every new role brings its own set of challenges. By and large, the Project Champions were passionate and pragmatic participants who were committed to the role they had undertaken and who dealt with the challenges encountered to the best of their ability. The overall sentiment from their involvement in the IWB project was that it was a positive experience for them personally, from which they learned a significant amount in terms of developing their

technical expertise in IWB technology and further developing their ICT pedagogical skills. Nonetheless, in terms of upskilling their colleagues in the use of IWB technology, and thereby affecting change in pedagogic practice, they were severely constrained by a number of factors, in particular their youthfulness and lack of any real authority in the system's "pecking order," compounded by an abdication of leadership by School Principals when it came to supporting them and the IWB project.

The Online Community of Practice

According to Wenger-Traynor (2015), communities of practice (COP) are "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly." Effective learning communities provide members with opportunities to build on the individual's and the group's knowledge, take risks without fear of failure, and develop expertise and experiences with many different activities. With the growth of web 2.0 technologies, teachers, like many professionals, are increasingly participating in online communities of practice, forum discussions, and other online activities to enhance their learning. According to Trust (2012), highly effective teachers learn through collaboration, professional development, and research into best practices.

Developing an online IWB Community of Practice was an important dimension of the project. It was envisaged that this resource would act as a vehicle to help teachers to develop and share materials and their learning experiences with IWBs as well as advancing their ICT skills through experiencing how social networking and communication tools could be used to support learning and reflection.

The project's online community of practice was built utilizing an existing eTuition COP hosted on a Ning-based platform which provided an online network for teaching and support staff working in the VET in Ireland and the UK. The underlying eTuition architecture contained a number of tools which supported teamwork and

community interaction, such as discussion forums, repositories for storing and exchanging content, blogs that could be updated on a daily basis, notice boards for communications, and personal profile areas containing photographs, contact information, and other relevant details of community members.

Unfortunately, teachers did not engage with the eTuition site. Hardly anyone interviewed had uploaded lesson plans to the site other than those which had been completed during training workshops. A check of the eTuition site itself confirmed this situation. Discussions with interviewees uncovered a number of reasons for teachers' nonengagement in the online COP, which on further analysis could be classified as technical issues, confidence issues, and work practice issues.

On a technical level, people found the eTuition site difficult to navigate and use. The site itself was viewed as "clunky," "cumbersome," "confusing," and "not very user-friendly." This criticism was universal across the board, from the most "tech-savvy" teachers and Project Champions to the most techno-phobic participants. Many teachers also expressed concern about the resources they created being visibly available to a wider audience. In part, this was due to a lack of confidence in the quality of the lessons they produced with some saying they were "*embarrassed about the quality of their own lesson materials*" believing they were "*not good enough*" or professionally polished enough to publicly share with others. For other teachers, the reluctance to share materials was tied up in fears about being judged by their peers and a belief that the time they invested in developing resources would not necessarily be reciprocated by others.

Undoubtedly, a large part of the reason teachers did not create lesson plans as requested can be explained by traditional work practice mores. As teachers are not obliged to work beyond their contracted hours, very few were willing to put in the extra personal time which preparing IWB lessons and coming to grips with the eTuition site involved. This was particularly true in the context of the prevailing political and

economic climate at that time, where, as a result of the collapse of the Irish Celtic tiger in the aftermath of the global recession of the late noughties, Ireland required an IMF (International Monetary Fund) bailout to keep its economy afloat.

Under this new regime, teachers had their salaries cut significantly, were forced to make higher pension contributions and were also required to work an extra 33 h per school year without any additional remuneration, under what was officially known as the Croagh (pronounced Croke) Park Agreement negotiated between the Government and Public Service Trade Unions. Effectively amounting to an extra 2 h per week during school term time, the agreement stipulated that the 33 h had to take place outside of normal school teaching time in order to avoid any erosion of class contact time. Colloquially, the extra 2 h became known as the "Croagh Park Hours." Across all levels of the education system, and not just in the VET sector, a lot of teacher goodwill and the voluntary ethos that had traditionally permeated the Irish education system was eroded as a result of these enforced changes. Unsurprisingly, when teachers saw how much their take-home pay was reduced, they resented putting in those extra hours, small as they may seem to an outside observer. Invariably this resentment affected project engagement. There are parallels here with findings from a later study on the adoption of iPads in a Portuguese school where years of austerity and cutbacks had also adversely affected some teachers' motivation and goodwill (Judge 2017).

The adherence to traditional work practices and ways of doing things was also evident in people's reluctance to engage with each other in the online space. Many teachers said that they could not see the point of online communications and the benefit for their professional practice. This is understandable when you consider that very few participants had ever undertaken online training before, participated in a community of practice or even collaborated with colleagues in their schools to share resources or develop teaching materials in the offline world, never mind the online environment. As one Principal observed, "*there's no point in having something online when*

they don't meet face to face anyway to discuss common areas" and another noting *"we already have a community of practice – it's called a staffroom where we all meet each other daily and interact."* Furthermore, teachers themselves admitted to preferring face-to-face communications and attending training delivered in a physical setting rather than in a virtual space. All these findings point to a culture, a *modus operandi*, and a mind-set among both principals and teachers that was very traditional indeed.

Conclusion and Final Comments

This case of an Irish IWB project provides a window in which to view what Selwyn (2010b) calls "the messy realities of digital use in schools" which in this instance manifested itself largely as a form of nonuse. As he also argues, the technologically deterministic orientation of much academic scholarship on ICT in education has done a disservice to the process of ICT adoption and integration in schools by ignoring the socially shaped contextual nature of school-based technology in which economic, political, organizational, and cultural factors all have a part to play. The multitude of factors that inhibited the adoption of IWB technology in these VET schools illustrate clearly why a sociocultural perspective can help us better understand the complexity of ICT adoption in schools. No single isolating factor was to blame for teachers' lack of engagement. The story here was much more intricate, much more complex, and much more nuanced when examined using a sociocultural framework to unpick the various layers.

Firstly, looking at the macro context, it is clear that the wider international/national political and economic climate which no school authority had any control over played a part, as teacher resentment over altered pay and conditions and mandatory unpaid hours rose to the surface when asked to invest more personal time in technology upskilling. In venting their frustration about the time required to master IWB technology and the accompanying Community of Practice, their anger was not directed at the project per se, but

more at the political and economic situation they found themselves in, which were completely external to the project. Consequently, the project became a vehicle, which allowed them to publicly articulate their anger about their altered circumstances, probably for the first time, in any meaningful way by downing tools through little or no engagement. As a result, the project, and with it the IWB technology and the Community of Practice it sought to introduce, became a victim of the more global macro context affecting all areas of Irish life, including schools and teachers, at that point in time.

Secondly, at a meso or system level, issues involving the introduction of a new national curriculum, school leadership and institutional arrangements such as inconvenient scheduling of activities and lack of resources were also influential. In terms of the new curriculum, teachers felt they were already stretched and overworked trying to meet its demands. With competing demands from two new initiatives, they viewed the design and implementation of new curriculum modules rather than upskilling on IWBs as their key priority. Teachers are by nature pragmatic people and no different from other professionals in that they know that what gets measured gets done. There were no real sanctions for the individual teacher or individual school if they did not adopt IWBs or did not engage in the Community of Practice. In contrast, no teacher wants to incur the wrath of his or her Principal or District School Inspector by not completing module revisions and redesigns on time for curriculum reform mandated at a national level. In this respect, there was a failure at central level in the VET system to anticipate that introducing a new technology to schools at a time when curriculum reform was also being implemented might prove problematic.

There was also a failure of school leadership. The successful implementation of any new school initiative including technology depends on leadership. By its very nature, school innovation involves change and as an initiator or implementer of change, the principal plays a crucial role (Sarason 1996). It is the principal who sets the tone when it comes to promoting new projects and encouraging teachers to integrate ICT into

teaching and learning, as well as building the organizational capacity for change. Both the attitude and the behavior of principals are clearly noted by staff and have a significant influence on how staff think, behave and act. Principals needed to buy into the project; rather, they had adopted a hands-off approach in leaving so much of the project's implementation to the Project Champions, most of whom were too young and too inexperienced to handle the organizational change implications which ICT projects like this one inevitably involve. It is no surprise that leadership support, or lack thereof, can make or break the adoption of innovations involving new technology, as it is principals in their capacity as school leaders who ultimately influence how teachers and schools embrace innovation and respond to change.

Finally, at the individual and micro level, some of the most important issues that emerged had strong cultural underpinnings. Although hard to identify as it is largely implicit (Schein 1992), sociologists believe that culture is the context in which things happen in society, institutions, and organizations. The concept of culture which Boas (1930) defined as "the social habits of a community" and Smith and Bond (1998) as "systems of shared meaning" or more simply by Deal and Kennedy (1983) as "the way we do things around here" is ultimately intertwined with organizational norms and values which influence and shape how groups and individuals think. That is why Sarason (1990) suggests that school culture must be taken into account when trying to gain a better understanding of the school organizational context in order to understand the dynamics of school systems and how its multiple contexts impede the success or failure of innovative CBT endeavors. As Cuban (1984) reminds us, "the cultures of teaching that have developed within the occupation tilt towards stability in classroom practices." This means that teachers and schools are fundamentally cautious, prefer stability, and are skeptical when it comes to implementing or adopting change presented by new methods or new CBT technologies.

In particular, the difficulties associated with the e-Tuition Community of Practice boil down essentially to the problem of culture and the interaction between dominant organizational cultures and change when new technologies are introduced. It has long been acknowledged that the predominant school culture tends to be individualistic, with teachers working in isolation. The structure of the typical school day affords little opportunity for teachers to work together or to exchange ideas on a sustained basis when compared to other professions. This problem is accentuated in the Irish VET sector due primarily to the number of teachers working part-time where time physically spent in the organization is very much confined to the classroom, affording few opportunities even for small things like "water cooler moments or conversations." Therefore, when new technologies such as IWBs or the eTuition site come along with the potential to develop new professional practices, they challenge the way teachers traditionally work and how they communicate, interact, and share with each other, thereby bringing to the fore many deeply held beliefs about what teachers do and how the school and teaching culture operates. Because there was no tradition of VET teachers working together both within and across schools in the offline space, expecting them to work together in a virtual environment was always going to be challenging.

In summary then, based on the findings and discussions in this entry in relation to the deployment of CBT in schools, a number of lessons have been learned about the factors affecting its adoption, particularly when it comes to teacher CPD, which are best summed up in Table 1.

To conclude, the issues and roadblocks reveal the extent to which the introduction and adoption of new technology for CBT is fraught with challenges involving not just technological competence but also professional and organizational cultures, involving how people and the school system react to changes implicit in the adoption of new technology. When viewed through a sociocultural lens, it is easier to see how the biggest challenge facing ICT adoption and CBT in

Computer-Based Training and School ICT Adoption, A Sociocultural Perspective, Table 1 Key factors, constraints, and lessons for CBT adoption

Factor	Constraints	Lessons learned
Initial Training	Overly didactic and theoretical	Replace “Show and Tell” with hands-on and experiential learning.
Insufficient time	Lack of time to practice and develop resources	Allow sufficient time for teachers to practice and develop resources in order to confidently integrate CBT in classrooms.
Bad timing	Tension between project demands and national curriculum reform agenda	Timing is important, so where possible, avoid introducing new technology projects in schools when teachers are already working on other innovations, especially those with nationally mandated deadlines.
Staff contracts	Part-time staff are paid for teaching contact time only	Build training time into part-time teacher contracts so that they can up-skill on CBT as needed, particularly when it comes to new initiatives.
Project champions	Age level/experience and lack of leadership support	Recruit senior staff as Project Champions who have sufficient experience and gravitas to drive CBT projects; ensure School Principals are fully supportive of any new technology innovation.
Online community of practice (COP)	Technical difficulties and traditional work practices	Remove technical obstacles to teacher engagement with COPs by using platforms built on up-to-date technologies that are user-friendly and intuitive; recognize that traditional work practices present many practical and conceptual constraints to teachers’ engagement with a COP.
Sociocultural	Global, national, institutional, local, professional and individual contexts	Adopting a sociocultural perspective to the process of CBT adoption in schools reveals how a complexity of factors operating at macro, meso, and micro levels influence how schools and teachers respond and react to innovation and change.

schools is not so much about acquiring new technical skill-sets; rather, it is more about shifting mind-sets in terms of thinking and operating differently as teachers and as organizations, in the face of new technologies that offer a different and new way of working, thinking, and learning.

- [Rationales for Information Technology in Schools, Historical Perspective](#)
- [Smart Board Technology in Higher Education Institutions](#)
- [Support for School and Institutional Improvement and Accountability](#)
- [Teacher Education, Thinking About ICT](#)
- [Technology Enhanced Learning](#)

Cross-References

- [Adoption of Innovative ICT-enabled Systems for Analysis- and Intuition-styled Teachers in Primary Schools](#)
- [Computers in Secondary Schools](#)
- [Computing Education, Outcomes of](#)
- [IT in Educational Institutions, Planning and Development of](#)
- [Leadership on Information Technology in Education](#)

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Computer-Mediated Learning

- [Computer-Assisted Learning](#)

Computer-Oriented Language

- [Programming Language Selection for University Courses](#)
- [Teaching Computer Languages in Universities](#)

Computers

- [Educators and Children Perceiving Affordances with Working Technologies in Early Childhood Settings](#)

Computers and Educational Improvement

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Synonyms

[Computer assisted learning](#); [Computer-based management information systems](#); [Digital learning](#); [Education technology](#); [Educational communications technology](#); [E-learning](#); [Information and communications technology](#); [National grid for learning](#); [School improvement](#)

Introduction

This entry deals with the intersection of the use of computers (mainly in state or public rather than private or independent schools), dating from the late 1970s to the present day, with educational improvement (also in schools). It draws on experience in the school systems in the United Kingdom (UK), with examples from Northern Ireland (NI) in particular, although aspects refer to educational technology contexts across Europe.

As has been recognized for some 20 years and, as will be argued in this entry, uses of digital information and communication technologies (ICT) are deeply and irremovably embedded in a multifactorial way in many aspects of the life and work of schools, all of which contribute collectively to school improvement (NFER 2000; OECD/CERI 2001). Computer technology applications which are focused on one aspect of learning and teaching, leadership and management, or professional development may well make a valuable contribution to improvement, but the premise of this entry is that it is the organized, holistic, whole-school approach which makes the difference to school improvement.

Overview

This entry summarizes the evolution of computers and their place in schools over the past 40 years and outlines how educational applications and content developed as the technology advanced. These developments are then related to improvement in the context of pedagogy and the school curriculum, drawing on the UK as a context.

The entry then deals briefly with how the UK government responded to their recognition of the link between computer use and educational improvement and goes on to explain how, as a result, the growing diversity of educational technology is now embedded across the life and work of schools.

In dealing with the role of technology in teaching, assessment, and learning, the entry sets out:

- How the teaching and assessment of related skills evolved from ICT user (“e-skills”) to higher-order thinking skills and to a

progressive framework for digital skills, using Northern Ireland as an example.

- How technology can be embedded in ways that can raise standards, especially through the pedagogic quality of educational applications.

The entry ends with shorter sections on the role of computers in supporting improvement in the management and leadership of the school and in how digital and online technologies are used as a professional tool by teachers as practitioners to improve their practices.

Educational improvement is a theme that flows through all sections.

The Evolution of Computers and Their Place in Schools

The variety of different ways in which computers are used in schools today derives from the evolutionary stages of development in hardware and software over the past 40 years. During the 1970s, only a few UK schools used mainframe computers in teaching computer science. A national government programme, the National Development Programme for Computer Assisted Learning from 1973 to 1977 (McDonald 1977), developed projects in the use of mainframe computers focused on their use for learning in subjects other than computer science. It supported some 35 projects, mainly in tertiary education, but seven of which were in school subjects where content resources and algorithms to help learners manage their learning through computer-based tests were developed.

The first microcomputers appeared in schools in the UK in the late 1970s. The Commodore PET microcomputer had a small, green-text display screen and an audio cassette tape for data storage. The programming environment and programs had to be loaded every time the machine was switched on, and any new program saved to cassette before it was switched off. The most that could be done from an educational point of view was to write code, in BASIC (a simple programming language) or in PILOT (an authoring language)

for elementary skills drills and multiple-choice quizzes for a single user at any one time, representing a very limited model of pedagogy (teaching and learning). Users could also develop early examples of control technology, by programming simple robotic projects (interfaces easily addressable with machine code) that controlled, for example, model railways and model toys and lights.

In the early 1980s, the Department of Trade and Industry, following a ministerial initiative from (now) Sir Kenneth Baker, introduced a “Microcomputer in School” scheme, to provide direct access to at least one microcomputer in each school by the end of 1982, with the dual intention of supporting the British microcomputer industry (Acorn Computers, Research Machines and Sinclair) and supporting teaching and learning, both *about* computers and *with* computers. During the 1990s, as the number of computers in a school grew, networked but stand-alone computer rooms were constructed, which allowed the pedagogy to evolve from demonstration of a software package by the teacher to a group of pupils clustered around a monitor to whole-class computer-based tasks and activities, often using drill-and-practice programs, typically to practice simple skills or to run an instructional package.

More recently, in the late 1990s onwards, as the Internet spread in availability, initially through school connectivity to university-based networks such as JANET (the Joint Academic Network), school computer rooms were connected to the Internet. Later, in a planned and systematic way across the UK, Regional Broadband Consortia (10 consortia in England and one each in Wales, Scotland, and Northern Ireland) were promoted as a UK government “National Grid for Learning” initiative (NEN 2018). Schools invested in wired network infrastructure around the whole building allowing, at the very least, a computer on each teacher’s desk (largely for simple administrative recording tasks such as attendance) and some clusters of computers for specific learning purposes in, for example, technology and art rooms. For a period of time, from around the early 2000s, interactive “whiteboards” installed at the front of a classroom were popular with teachers because

they were in the “teacher’s space” and supported readily a didactic, show-and-tell, whole-class style of teaching. However, the interactivity which they afforded was rarely exploited by teachers (despite some very imaginative interactive educational software) who tended to use the device as little more than an expensive data projector.

Eventually, by the early 2000s, digital computer devices became, generationally, smaller and more mobile. With the introduction of wireless networks in schools and the evolution of web-based software environments, laptops and handheld digital devices became, initially, a supplement to computer rooms and then pervasively, personally used and individually owned tablets and smartphones supporting an “always-on” Internet connectivity.

The Development of Educational Content

As computer technology advanced over the decades, with increasingly more powerful and faster microprocessors, it enabled software applications which moved on from simple skills training programs, through simulation packages with increasing sophistication, through to productivity and design packages which put the control of design and development of applications into the hands of the user, with greater ease of use, more accessibility, and less and less specialist user training needed.

As processing power, display unit capability, and storage devices improved, graphics were used to illustrate and animate processes which could help to illustrate and animate for a learner how systems or processes (mathematical, physical, chemical, biological, environmental, technological, and so on) worked – initially like an interactive display which the teacher could use to “show and tell.”

The quality of rendered graphics improved, becoming less diagrammatic and more realistically “lifelike,” to the point today where computer-generated images are often undisguisable from a video or filmic presentation. At the same time, the

increase in the number of computers in each school, and especially on networks, opened up the potential for learners to be in control of and explore an educational package (at least where the teacher made the pedagogic decision to plan the learning activity in that way) – affording a potential step change improvement in pedagogy.

However, not all innovations led to an improvement in outcomes. In the 1990s, Integrated Learning Systems (ILS) were popular in the United States of America (USA) and were supported by some large educational corporations. The UK government, seeking a solution for literacy and numeracy challenges, supported an evaluation of suites of networked packages that provided individual tuition in mathematical and language skills. The evaluation revealed that teachers varied in their appreciation of how to build their use of ILS into their teaching and that, while careful use could improve the test score of some learners within the ILS package itself, it did not often lead to all-round skills improvement in literacy and numeracy (BECTA 1998).

As educational programs became much more sophisticated, they required a much higher level of programming skills, leading to educational programs being written by computer programmers, with sometimes very little understanding of teaching and learning. As the market for educational software grew, there was an explosion, initially in the UK, of educational companies being set up and run by teachers, producing very sophisticated educational packages, especially for the larger primary school markets.

The greater ease of online communication through Internet-connected computers also made its contribution, enabling pupils across the world to communicate and learn together through some remarkable projects (Austin and Anderson 2007; Austin and Hunter 2013). However, the impact has been much less on education in schools compared to that at the tertiary level, both of which pale into insignificance compared with the uptake of online computer gaming; but then, online gaming has grown as a new enterprise, unlike education systems which work within an existing set of institutional frameworks which are often, by their

very nature, conservative, resilient to innovation, and slow to change.

Given the evolutionary story, it is unsurprising that such a variety of terms have come to be used in this field: computer-based education, computer-aided learning/teaching, educational computing, information technology, educational superhighway, microelectronics education, digital technologies, information and communications technology (ICT), and educational technology.

The Breadth of Improvements Across the School Curriculum

In the early stages of introduction of microcomputers in schools, in the 1980s, the prime argument for their use was to develop the pupils' elementary computer-based skills in programming or computer literacy for the purpose of enhancing their employment opportunities (Passey 2014). As the software available in schools evolved and could be used more readily, without recourse to elementary programming, teaching focused on using so-called "productivity" tools (word-processing packages, elementary spreadsheets, and presentation packages such as Microsoft PowerPoint). Simplified versions of such packages were marketed (such as Edword, e.g., a word processor designed for use in schools) to improve accessibility even further.

Since the 1980s, ICT and digital, online educational technologies have had broad and continuing implications for the school curriculum. In the UK (England, Wales, and Northern Ireland), the Microelectronics Education Programme (MEP) (Fothergill 1981) set out to innovate, introducing electronics, microelectronics and its systems applications, including control technology, to what had been previously a craft-based technology subject. It updated computer studies from the mainframe era to the microcomputer generation, injecting computer-aided design, data logging, and data processing not only into computing but as educational tools into art and design, science, and mathematics. Word processing and other electronic office techniques

updated commercial studies and typewriting classes. The use of the computer as a means of storing and retrieving information in databases and the associated information systems was developed as a means of supporting learning and developing information-handling skills, initially in business studies, but more widely in a greater variety of subjects.

Furthermore, MEP promoted educational content development to assist learning (CAL, computer assisted learning) across the primary and secondary curriculum, as a guide to learning for the individual, as a learning aid for small groups of learners, or as a system for the whole class. Innovation was not limited to microcomputers but also to microelectronic devices such as robotic kits and computer peripherals for music, for art, for technology, and even for physical education and sports as well as turtle-based graphic devices to support elementary programming skills using the programming language Logo (Papert 1993).

It was the development of computer peripherals, special keyboards, and data entry devices which led to improvements in teaching for special educational needs by opening up access to computer-based learning for those with physical and other disabilities.

Government Responses to Computers and Educational Improvement

Not all regional or national education systems responded strategically to the challenges, threats, and opportunities of an emergent digital age, but where they did, they saw it initially as an attempt to build up industrially and commercially relevant skill - sets among young people through teaching *about* technology. The development of a rhetoric about using technology to improve the effectiveness of education – learning *with* and *through* – followed, and the debate about its relative success or failure in that regard persists today. The aim of the MEP, which inspired similar initiatives across Europe and beyond, was "to help schools to prepare children for life in a society

in which devices and systems based on microelectronics are commonplace and pervasive” (Fothergill 1981, p. 1). At that time, in the UK, there was no nationally prescribed curriculum, so it was necessary for MEP to promote and encourage improvement in schools “to respond to these changes by amending the content and approach of individual subjects in the curriculum and, in some cases, by developing new topics... with the dual aim of enriching the study of individual subjects and of familiarising pupils with the use of the microcomputer itself” (Fothergill 1981, p. 1).

The strategy for MEP went on to propose that “use should be made of the microcomputer to develop the individual pupil’s capacity for independent learning and information retrieval” (Fothergill 1981, p. 1), an aim which set sights directly on improving pedagogy in the classroom.

The UK government continued to intervene in educational improvement through technology by investing in 1998 with a £700 million development of a *National Grid for Learning* as an infrastructure and service for networked learning by connecting all 30,000 schools to the Internet by 2002 (Open for Learning, Open for Business 1998).

Its targets included:

- ensuring that serving teachers feel confident and are competent to teach ICT within the curriculum and that librarians are similarly trained;
- enabling school leavers to have a good understanding of ICT, *with measures in place for assessing their competence in it*; and
- making Britain a centre for excellence in the development of networked software content, and a *world leader in the export of learning services*. (Barnes 2001, p.1)

The purpose of national investment was evolving into an expectation that different models of “learning services” would emerge which might provide educational efficiencies as well as improvements.

The White Paper (Open for Learning, Open for Business 1998) sets out ways of ensuring a wider

use of existing software resources and getting a better return on investment by engaging educators in improving teaching, assessment, and learning through more innovative “e-learning” and also by modernizing the curriculum to be more adaptive in a digital world.

We need a concerted effort by the digital content industry, innovative educators and education researchers together, to demonstrate what the next generation of e-learning could be. (Open for Learning, Open for Business 1998, p. 12)

In summary, as technology and software design and development has advanced over the last four decades, and where system-wide access has been facilitated and promoted by national or regional education systems, so have the affordances which digital technology offers to educators in terms of educational applications. Limitations and risks which are, at times, associated with the use of educational technologies are sometimes blamed lazily on “the technology” (Cuban 2001). Yet when evaluation projects about the “failure of technology” in schools are examined closely, they expose examples of poor planning and decision-making in instructional design, poor pupil and classroom management, and inadequacies in pedagogic skills, or some combination. More often, the studies ask whether or not technologies enhance learning, rather than asking when and in what terms they might do so.

How Educational Technology Is Embedded in Schoolwork

Digital technologies are still today inherently disruptive to established patterns of working, and as a result, their uptake and impact on day-to-day practice depend upon innovative, creative users who are willing to review and revise their practices. The same spirit of innovation, creativity, and reflective open-mindedness is also essential for practitioners who engage in educational (school) improvement: it is unsurprising that effective educational uses of technology and effective self-evaluation leading to improvement can often be seen hand in hand.

This entry now summarizes, in turn, the three major ways in which digital technologies have come to be embedded productively, in ways which can, used well, improve life and work in schools:

- The role of technology in teaching, assessment, and learning.
- Its role in supporting the management and leadership of the school.
- Its use as a professional tool by teachers as practitioners.

When it comes to educational (school) improvement, the central factor in raising standards in attainment is the quality of learning as determined by the effectiveness of teaching and the response of the learners. Crucially, a focus on high standards in pedagogy needs to be underpinned by a high-quality institutional culture and leadership of learning which is conducive to improvement through effective self-evaluation based on first-hand evidence. Given the centrality of learning and teaching, more attention is given to these components in the rest of this entry.

The Role of Technology in Teaching, Assessment, and Learning

Digital technology applications have become embedded in education in ways which, when (i) of a high standard themselves and (ii) appropriately and effectively employed to a pedagogically high standard, can improve teaching and learning in at least five ways:

- Where the use of technology supports the progressive development of what might be referred to as “e-skills”.
- By supporting and developing the learners’ higher-order thinking skills, especially where the specification of such skills is set out explicitly in the regional or national curriculum.
- By facilitating both formative and summative assessments to enable learners to make judgments about their learning and their own progress.

- Where technological devices play an explicit role in aiding the access of learners with specific physical and special needs to learning and teaching.
- Where the technology itself is a central resource in specific subjects.

This section considers the first four of the bullet points above.

Evolving from ICT User (“e-Skills”) to Higher-Order Thinking Skills

Where the main pedagogic approach has been teaching *about* computers and how to use them, there have been evolving definitions of ICT skills: from programming to productivity, to problem-solving, to systems design, and eventually to an ICT skills framework.

There have been attempts, over many years, as the digital and online technologies advanced, to provide a certified award for skilled computer users and to address the current and future needs of business and the economy and for employers by ensuring that the sector is equipped to compete in the worldwide digital economy. Certification is usually validated by some form of national training organization, sector skills council, or national computer society. Sometimes it targets explicit skill shortage areas, such as e-skills for females, and sometimes attempts to be valid across countries, for example, the European Computer “Driving” License.

While they have a limited, prescribed value in the employment market, they have in common that they are neither well attuned to the curriculum, nor to teaching approaches in schools, nor do they attempt to address the progressive development of skills from the early years of schooling through to tertiary education.

School inspectors across the UK have seen a common problem in a failure of learners to progress in skills development arising from the ICT courses taught in the first years of secondary schooling (Ofsted 2013). In the UK at least, the primary school curriculum, taught by one teacher to a class for the course of a year, provides considerably good opportunities for productivity tools to be used to enhance thematic projects,

drawing across the whole curriculum in an integrated manner.

Together with a very healthy market in education software for schools, packages designed to help teach specific skills (language and mathematics skills) have enabled children in the classes of more innovative and creative teachers to develop their computer “literacy,” that is to say their ability to use computers, in an incremental and purposeful manner. The problem in secondary schools, however, has been that not all children making the transition to the early years of secondary education from different primary schools have had the same enriching experience. Too often, in response, secondary schools designed ICT skills courses, often taught by teachers with some level of qualification in computer science, in which they painstakingly taught pupils about the hardware components of computer systems and how to switch them on to make them work.

In order to counter this passive approach to teaching *about* computers, rather than to use computers as a tool for project-based approaches to teaching across the curriculum (*teaching with*), various ICT skills frameworks were developed, partly to expand the understanding of teachers about the affordances of ICT and partly to enable pupils to be accredited with competence in a wider skill set.

The NI Curriculum Council for Examinations and Assessment (CCEA) was the first of such bodies in the UK to identify a set of ICT user skills (CCEA 2018a) which is designed to be embedded in learning activities across the primary and the secondary curriculum, with examples of work which could be assessed and accredited in the school’s choice of subject contexts. CCEA identified a set of *capacities* in the application of ICT (at a higher level than operational skills) which were adaptable in any curriculum context, enabling the embedding of ICT to bring improvements directly to teaching and learning.

These interlinked capacities are codified as:

- **Explore:** the searching, finding, and using of information with digital tools to investigate and solve defined problems

- **Express:** the creative use of text, sound, music, and images such as developing a multimedia product
- **Exchange:** communicating online to share thinking and to develop ideas
- **Evaluate:** to think about how the application of technology might be improved, with a problem-solving focus
- **Exhibit:** using online communication to show-case the done work digitally

Furthermore, in a number of education systems, attempts have been made to define skills relating to the use of the technology in *higher-order* processes, which relate to learning itself and not just the ability to use a computer for prescribed tasks.

Where a regional or national curriculum defines the skills and competences which are central to learning and working, for example, *thinking skills* and *personal capabilities*, these align much more closely to the productivity uses of ICT software and tools. Thinking skills and personal capabilities can comprise managing information; thinking, problem-solving, and decision-making; being creative; working with others; and self-management (CCEA 2018a).

Where the development of thinking skills and personal capabilities is an integral and required part of the curriculum, the development of these skills can help pupils to think critically and creatively. They can help them to develop personal and interpersonal skills and dispositions in a changing world, especially when learners use digital tools that help them to go beyond acquiring knowledge. In the NI curriculum, for example, in order to develop the learners’ thinking skills, teachers are required to design learning experiences that will encourage pupils to engage in better quality thinking. Tasks are designed to enable pupils to search for meaning, apply ideas, analyze patterns and relationships, create and design something new, and monitor and evaluate their progress. To develop the learners’ personal capabilities, the teacher can create opportunities for them to experiment with ideas, take initiative, learn from mistakes, work collaboratively, and become more self-directed in their learning.

Thinking skills can be facilitated readily by using productivity, critical and pathway planning and research tools, mind-mapping tools, databases and spreadsheets, information management and artificial intelligence systems, communication media, group work tools, and information assets. They include activities which can involve:

- Sequencing, ordering, classifying, and making comparisons
- Making predictions, examining evidence, distinguishing fact from opinion
- Making links between cause and effect
- Justifying methods, opinions, and conclusions
- Generating possible solutions, trying out alternative approaches, evaluating outcomes
- Examining options, weighing up pros and cons
- Using different types of questions
- Making connections between learning in different contexts

The learning outcome is intended to “show deeper understanding by thinking critically and flexibly, solving problems and making informed decisions” (CCEA 2018b). In this context, managing information involves asking, accessing, evaluating and selecting, being alert to error, recording, and integrating quantitative data and qualitative information. It can include:

- Asking focused questions
- Planning and setting goals, breaking tasks into sub-tasks
- Using one’s own and others’ ideas to locate sources of information
- Selecting, classifying, comparing, and evaluating information
- Selecting the most appropriate method for a task
- Using a range of methods for collating, recording, and representing information

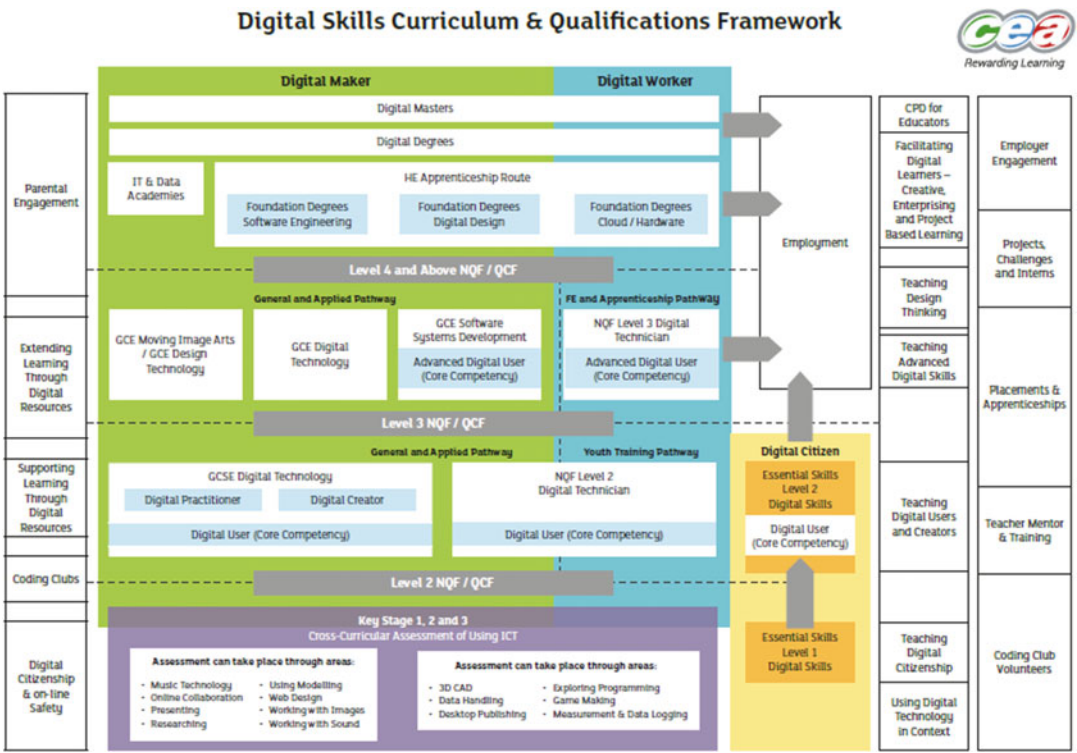
Over time, as it becomes apparent that low-level skill sets in employment are being made redundant through automation, government reports recognize that a premium is placed on more rapid progression to higher-order skills and thinking capabilities in the education system.

For example, the UK House of Lords July 2015 report *Make or Break: The UK’s Digital Future* highlights the impact of changing technology on the labour market and warns that education in the UK was not addressing the significant digital skills shortage in business and industry. It identified that females are underrepresented in digital jobs and there are insufficient apprenticeships and a shortage of medium- and high-level digital skills. In response, some of the recommendations in the report are that digital literacy should be taught alongside and complement numeracy and literacy. The report makes reference to the UK Digital Skills Taskforce’s three-band definition of different skills levels: digital citizen, digital worker, and digital maker, along with the UK Forum for Computing Education’s application of the definitions to the workforce (Department for Business, Innovation and Skills and Department for Culture, Media and Sport 2016).

The concepts behind the three broad tiers of digital skills can be applied to the context of a learner within a school setting. CCEA, for example, sets out that it wants to ensure that learners in schools could become:

- Digital citizens, with the skills that will enable them to take part in digital aspects of society, to communicate, to be informed, to participate, to buy and sell, to share, and to work safely and without hindrance.
- Digital workers, who are able to use tools, to process, to analyze, and to apply their digital skills to further their learning or in a work-related setting.
- Digital makers, who are starting to design, to build solutions, to create, and to invent and build.

CCEA recognized that merely being able to use digital devices is not enough to gain some forms of employment in the future. In fact, being able to use devices will be the basic standard required in any future employment, and increasingly young people will need to learn how to build things with digital devices. They will need not just to be able to program or code, they will need to



Computers and Educational Improvement, Fig. 1 Digital skills curriculum and qualifications framework

think logically and solve problems with different digital products. They will all need to become digital makers and workers.

CCEA developed a framework (Fig. 1) to show the clear progression of these digital skills for learners from the early years and foundation stage of education to public examination level post-16 and beyond into tertiary education.

Our framework is attempting to integrate digital skills across the education system, building thinking skills into the process of learning about digital devices and creating qualifications that are unique to Northern Ireland. (CCEA 2018c)

How Technology Can Be Embedded in Ways That Can Raise Pedagogic Standards

If technology is to make a difference, standards need to be high in five underpinning dimensions of provision:

- (i) Infrastructure provision
- (ii) Technical standards

- (iii) Content development
- (iv) Pedagogic affordances and practice
- (v) Institutional development

Other entries deal in detail with high standards in the technical delivery platforms – the hardware used, the underpinning network infrastructure, and high-quality software content/curriculum resources – the software used.

But successful educational improvement also depends on the culture and leadership of the institution – the school – and especially on the understanding and capacity of the leaders and staff in the processes of educational self-evaluation, based upon first-hand evidence, which leads to improvement.

However, the pedagogic decisions by teachers on what, when, and how to use digital/software assets depend on a good understanding of the affordances of the selected asset and will determine whether or not learning may improve by addressing successfully the identified teaching

challenge and the learning barrier or interest, in the way in which learner, teacher, and resource application interact.

Pedagogic quality refers to the quality of teaching, learning, and assessment activity using technology-based assets – resources and tools (Anderson and McCormick 2006). The quality of the content itself underpins the pedagogic quality, but it *affords*, rather than determines, pedagogic quality. The extent to which it leads to good pedagogic quality depends on the decisions and behaviour of teachers in selecting the appropriate resource/asset, designing and preparing for the interaction, and the understanding and skill of the learners throughout their engagement.

The axiom is: the greater affordance in the content design, the greater the scope for pedagogic quality; the narrower the resource design, the greater the understanding and the more decision-making which is required from the practitioner in designing, preparing, and offering the learning/teaching activity.

This can be understood by considering a number of affordance subcategories:

- (i) The **match of the resource to the curriculum**: the design of the resource needs to have clear objectives, which are relevant to the purpose, and enables the learner to engage in relevant learning activities which are supported by the nature of the assessment afforded.
- (ii) **Inclusion**: the resource serves the target user well; does not in its design (such as the language level) exclude any learner; accommodates to a range of different types of special need and any physical disability; and is inclusive to a range of social and ethnic diversity and gender.
- (iii) **Ease of use**: the resource is intuitive in use, needing minimal guidance; makes appropriate assumptions about the user's ICT skills; and is accessible/transparent to use.
- (iv) **Learner engagement**: the design engages the learner by being purposeful, enjoyable, supportive, and encouraging and creates a good ethos – a good atmosphere and experience for learning; it is flexibly designed and can be used in creative ways from very simple to very complex; it is readily in the control of the learner by being largely transparent to use in ways which do not interfere with the learning purpose; and it integrates easily with other software tools or assets.
- (v) **Effective learning**: it takes innovative approaches and makes effective use of digital affordances; it supports a range of uses allowing a good match to how the learner approaches learning; it supports diverse learning styles while extending the users' repertoire of learning approaches; it may accommodate a didactic approach to teaching as well as independent use by the learner; its activities facilitate collaborative learning and contribute to problem-solving skills and sharing and explaining information; and it acts as a catalyst for creative and group thinking and as a tool "to think with."
- (vi) **Effective outcomes**: it promotes the characteristics of agency by the learner; it engages the learner in thinking (even where the learner is just responding by clicking a mouse); it affords control of pace and control of the paths through the material; and it enables and encourages metacognitive thinking (e.g., by asking the learner to reflect on their responses or approaches to the activity).
- (vii) **Authentic materials**: any material content should be a good representation of the ideas or situations that are present in the world outside (in other words, an element of realism without necessarily being realistic), and the materials should be appropriate to the personal orientations, prior knowledge, and experience of the learner.
- (viii) **Formative assessment**: the assessment element should support learning by providing rapid feedback on how to improve and opportunities for peer assessment and self-assessment.
- (ix) **Summative assessment**: the assessment provides grading/scores which are valid

and reliable; are comprehensible; deal with a range of achievement; and are non-adverse by not creating a negative response from the learner.

- (x) **Value for money:** given the inherent costs of using an ICT-based approach, does it have the potential to demonstrate cost-benefits or other indicators of value for money over any other approach?

The Role of Computers in Supporting the Management and Leadership of the School

Computer applications play an indispensable role in school administration, as they do in any enterprise. Over time, the separate administrative database applications have been developed into integrated, whole-school systems and therefore have evolved from helping senior staff manage separate aspects of the daily running of the school to helping all staff to drive improvement by supporting the integration of first-hand evidence about the effectiveness of teaching and learning for the purposes of internal and external accountability and leadership decision-making. Systems provide evidence to support decision-making not only by leaders but also by governors, for external accountability to the school service and for timely and relevant information for parents and the school community.

Schools hold increasingly detailed information about staff and students. For the student, this is not only about their background circumstances which impact on their engagement but also in tracking their progress through a school in terms of their attendance and behavior, and especially by turning assessment and test data into usable information which can help set performance targets for learners, taking their pastoral needs into account in supporting their learning, and identifying and making necessary interventions through personal learning plans.

Technology has made it easier for teaching and pastoral care to come out of their separate silos and merge, to the benefit of the learner. Integrated

management systems mean that the systems can be set to maintain elementary monitoring across the different data sets about each learner, with flags set to draw the attention of the relevant staff when agreed parameters (e.g., for attendance, behavior, test performance, costs, and so on) reach critical levels which merit intervention.

Costs drawn from the financial data of a secondary school can be correlated across the deployment of staff to provide specific subjects, the uptake of those subjects, and the relative examination success to determine the cost-benefits of the school curriculum. Similar correlations can be done to assess the cost-benefit analysis and the value added by the deployment of classroom assistants.

The performance management of teachers is also assisted by analyzing the performance of class and student groups, comparing the progress of and outcomes for similar cohorts in similar subjects to help inform decisions about the best way of deploying and timetabling the variation of expertise across the school workforce and providing targeted support to teachers where there may be underperformance and for their necessary improvement as professionals.

The Use of Digital and Online Technology Professional Tools by Teachers as Practitioners

Teachers themselves, and especially as professionals who are engaged in improvement, come to rely on online technologies in their day-to-day planning and preparation of lessons, identifying teaching and learning resources (increasingly using digital assets) and in evaluating the progress of learners through the evidence of tests and online questionnaires for their learners.

Management information systems are also used to support group management tasks, for example, jointly authoring and managing the complete cycle of school and department/phase developmental and action planning. Online group memberships can be managed across the organization; shared network folders and shared

writing of planning documents can strengthen collegial cooperation and collaborative working in a practical way. The systems provide a means of monitoring, recording and self-evaluation processes, and identification of priorities and actions through to detailed activity allocation and tracking of progress and achievement.

Management information systems also provide tools for creating and analyzing online questionnaires which are used for a variety of consultative and evaluation purposes, for example, the determination of collective views on policy; assessment of attitudes to change across staff groups; consultation with parents and the wider community on their views of the effectiveness of the organization; and questionnaires for learners to test their progress in curriculum-based knowledge and skills and to evaluate their views as learners about the effectiveness of classroom approaches adopted by the teachers and the response to initiatives to promote their wellbeing and protect their welfare.

With some half of the teaching workforce in many education services being of the age where they have used computers and the Internet and have learned, worked, and socialized online since they were students, they do not countenance any other way of working. Unsurprisingly, they turn to social networks in seeking contributions to their own professional learning and development, sharing ideas and resources, and discussing solutions to specific teaching challenges. Webinars and online workshops, some of which offer certificates of participation, credits, or digital badges, provide opportunities to learn with educators from universities and specialist teaching organizations and to network with and learn from the experiences of other teachers all over the world, who discuss how to engage learners, manage the classroom, and create engaging learning experiences. Some online environments are more structured. They provide teaching related to curriculum content or skills such as digital storytelling, data visualization, and critical media use to support all curriculum areas.

In some education systems, professional teacher organizations, such as teaching councils and professional bodies, have created online

portfolios for teachers to enable them to create, to control, and, if they wish, to share their portfolio for their own professional learning and career progression purpose.

The developments described here represent a more fundamental underlying shift in teacher professional learning from the dependency culture of teacher in-service education courses to the growth of self-sustaining communities of practice.

Those teachers who are more innovative in their practice, make use of online learning environments to publish their course contents, teaching materials, study resources, including multimedia productions, and self-assessment quizzes for their pupils to access either in the school or at home. They employ closed discussion boards, instant messaging, or email groups as a form of socio-educational media to host teaching exchanges and discussions with course groups and classes.

Once teachers have published their courses online, some begin to explore improved pedagogic models such as blended learning and flipped learning (where some of the teaching takes place online). However, teaching online requires specific teaching skills and research into the most effective responses into challenges about how to build an effective and safe online community, how to relate it to classroom teaching, how to foster active participation and engagement by learners, how to design and manage formative and summative assessment online, and how to strike the most effective study/life balance and to manage the risks of learning performance-induced stress.

Conclusion

In a powerful combination of ways, the various and very different roles of technology in schools, which were used initially as separate tools (for administration, for teaching, for testing, and for learning), have collectively changed all aspects of teaching professionalism. Initially, they enhanced existing provision (and in some schools that is still all that they do), but elsewhere, they lead to change and they shape whole-school improvement.

Over the past four decades, different applications of digital technology in schools have spread out like a series of distinct ripple patterns emanating from separate pebbles thrown into the metaphorical “pool” of school life and work. The ripples have intersected and are creating a dynamically holistic disturbance which is more than just “disruptive” to the surface of life in schools. They are increasingly affecting the underlying currents and wave patterns of what skills and knowledge need to be learnt, what it means to teach and to assess learning, and, fundamentally, what “learning” itself might mean in a digital world. It is impossible now to think of schools, as complex organizations, dealing with the complexities of learning and teaching in a social environment, highly dependent on information/data and on developing the necessary skills (for learner, teacher and leader alike) of information-informed decision-making, operating effectively without the multifaceted ways in which technology supports the endeavor of schools, leading to improvement in the interests of the learner.

Cross-References

- [Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption](#)
- [Decision Support Systems and Knowledge Management in Education](#)
- [IT in Educational Institutions, Planning and Development of](#)
- [Leadership on Information Technology in Education](#)
- [Support for School and Institutional Improvement and Accountability](#)

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Computers in Education

► [Computers in Education in Developing Countries, Managerial Issues](#)

Computers in Education in Developing Countries, Managerial Issues

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Synonyms

[Computers in education](#); [Information communication technologies in education](#); [Innovation in education](#); [Malaysian smart schools](#)

Definition

Computers in Education in Developing Countries: Managerial issues include the inclusiveness of computers in education program for different institutions and different localities, the cost involved, transferability of the affordance of the technology implemented, and the social effects for the viability of the innovation.

Introduction

Information communications technology (ICT) has the potential to increase the productivity and economic growth of a country. The World Bank Group (WBG) (2012) has been encouraging innovations in ICT as it seems to increase a country's competitiveness and enable economic opportunities for more IT-based services industry within the country. This is especially significant for countries with poorer economies. ICT products and services which cater directly to the

society in these countries enable the diffusion of technology across the economy, thus accelerating economic growth and building human capital (Lubin 2018; WBG 2012; World Economic Forum 2015).

In Malaysia, the ICT revolution came about when the Multimedia Super Corridor (MSC) was established in 1996 with the aim of building a sustainable ICT industry (Economic Planning Unit (EPU) 2001). By 2005, a total of 1,421 companies with MSC status were involved in the ICT industry, thus increasing the job opportunities in this sector (EPU 2006). By 2015, ICT-related industries, including e-commerce, contributed to 16.8% of the gross domestic product (EPU 2015). Malaysia has shown exemplary growth in the ICT sector which has in turn impacted economic growth and human capital development. This was also confirmed in a study which recorded ICT investment carried out by the private and public sectors during the period 1992 to 2006 which had a significant impact on Malaysia's economic growth (Kuppusamy et al. 2009). Hence, ICT has impacted economic growth and human capital development in Malaysia. The success of Malaysia and other developing countries in developing this sector has been the rationale for poorer countries to prioritize on ICT and to introduce computers in education.

However, ICT may not contribute to the overall economic growth of a country. The World Economic Forum (2015) reports that only rich countries seem to benefit from ICT for innovation, while in poorer countries, this results in a wider digital divide. In the poorer countries, the portion of society which have been induced by technological innovation have benefited and advanced in skills, but the rest of society may not have even acquired the minimum knowledge and skills and are left behind. Hence, the reported progress of a developing country in ICT may not indicate that a digital divide still exists and that there is a non-inclusive growth in human capacity (WBG 2012). A more inclusive program to involve all levels of society in human capital development for ICT is required.

In this entry, the definition of the developing countries is based on Lubin's (2018) definition and refers to countries which are less advanced industrially, have smaller economies than developed countries, and may have populations with lower levels of education, life expectancy, and household income. Lubin (2018) also identified that the more critical group of developing countries are the smaller countries with small populations and low-income status which represent a large portion of the world's independent states. These small developing countries are heterogeneous in their cultural heritage, languages, identities, and behaviors and have much to contribute in terms of educational technology research on implementation, policies, and practices of educational technology (Lubin 2018).

At present, literature on these developing countries is lacking, perhaps due to the smaller population of these countries (Lubin 2018). At the same time, implementing computers in education programs does not come without any problems. This entry hopes to outline some of the managerial issues which may arise in the implementation of computers in education program, such as inclusiveness, cost of investment for the technology and the social environment, building human capacity, as well as policies for designing the instructional environment and developing the infrastructure. Malaysia is used as an example for sharing efforts made during the implementation of their computers in education program, via the Smart School program.

Inclusive ICT Education Programs

The key to developing productivity in ICT lies in developing human capital for the industry. Hence, an inclusive education related to ICT should be emphasized. Education technology is seen as a solution to address the problem of the digital divide and non-inclusive growth in human capacity in developing countries. Ensuring that the computers in education program were provided at all levels of education, primary and secondary, as well in rural and urban areas,

would reduce the digital divide. Hence, introducing computers in education may spur social and economic growth to alleviate the country from poverty to a more developed status.

In the case of Malaysia, the Smart School Pilot Project was implemented for 88 schools in 1999 and rolled out through the "Making of Schools Smart (*Pembestarian*) Programme" at the end of the pilot project (Alias et al. 2013). The Smart School program was inclusive as all 10,000 schools in Malaysia were equipped with laptops, computers, and instructional materials through various ICT-related programs such as the School Laboratory Project and the Teaching of Mathematics and Science in English (Alias et al. 2013). The aim of these programs was to develop a technology-literate workforce for the information age. The program was inclusive and aimed to reduce the digital divide among the rural and urban schools.

The Malaysian government has seen the return in investment in education as the number of jobs in the ICT sector has increased. Documentation of the numbers of workers in the following ICT sectors from 2000 to 2002 indicates an increase in ICT-related jobs: software consultancy and supply, 80.6% (7,642 to 13,799); data processing services, 226.9% (809 to 2,645); database activities, 44.7% (472 to 683); and maintenance and repair of computers, 127.7% (628 to 1,430) (Kuppusamy et al. 2009).

Implementing computers in education programs has benefits for the country as the technology-literate workforce can bring about economic growth and productivity for the nation. However, consideration has to be made to ensure that human capacity development is inclusive and provided to all layers of society. This is so as not to increase the digital divide between the "haves and" the "haves-not." Developing countries do not want to be left behind in the ICT revolution in the globally competitive world, but policy-makers and managers in these countries should be aware of issues which may arise (Lubin 2018). While providing inclusive computers in education program may be necessary for economic growth, the concern is the high cost of investment in such programs.

Cost of Investment

There is a substantial investment involved when implementing computers for education. The Smart School Pilot Project (1996–2002), which was a fully integrated solution encompassing instructional materials (courseware), hardware, and change management, cost the government of Malaysia USD 78 million (RM 300 million) (Ng 2010). And this pilot project involved 88 pilot schools. Rolling out the solution to the other 10,000 schools had to have most cost-effective measures. The computer lab model (School Laboratory Project) and laptops for teachers involved in the Teaching of Mathematics and Science in English were completed in phases (Alias et al. 2013). Many developing countries might not be able to afford such high costs and need to depend on other assistance.

Monetary and other assistance for modernizing education in developing countries have come from developed countries and international organizations such as the World Bank. In many cases, the developing countries have no barriers and welcome the international assistance from the richer countries without question (Lubin 2018; WBG 2012). Sometimes, hardware such as computers and servers are provided as aid for computers for education programs as one-off projects and may not come with support for the use of the hardware. In accepting these aids, or even when considering the purchase of a technological solution, the policy-makers in developing countries need to consider the effects of the implementation and whether there is sufficient support for the hardware and instructional materials provided.

Hence, when considering the solution for the computers in education program, the question that managers implementing technology need to ask is whether similar solutions implemented previously in a developed country would have the same affordances and beneficial outcomes in the developing country.

Transfer of Affordances of the Technology

The first consideration is whether there is *innate transferability of technological affordances* (Lubin 2018). A developed country may have

been using a specific technology successfully. However, when the same hardware was provided to the developing country, it may not be useful. As an extreme case, computers provided to a developing country with irregular electrical supply or slow Internet speeds in some parts of the country might not be switched on, and the software applications which require a broadband connectivity, might not be used.

Malaysia had addressed this problem of *innate transferability of technological affordances* in these two aspects. There are remote areas in Malaysia with no electrical supply. The computers and laptops provided to schools would not be useful without electricity, and hence its usefulness would not be transferable to these schools. The problem of the lack of electrical supply was solved by providing diesel-driven generator sets for remote schools with irregular electrical supply. Similarly, Internet connectivity was a problem in remote areas. In order to use the virtual learning environment (FrogVLE) provided for schools, Internet connectivity was required. Hence, the affordances of the FrogVLE were not transferable without Internet access. In resolving the problem of Internet connectivity, the government provided 1BestariNet since 2012, for broadband connectivity to all schools, with schools having an option of undertaking additional Internet service providers with network connectivity in these specific areas.

In addition to the hardware, managers may also need to consider the *innate transferability of technological affordances* of the software applications and instructional materials provided. The delivery of these applications and materials should be suitable for the needs of the students in the developing country. Some software applications and instructional materials (courseware and e-materials) may be very interactive and stimulating for learners but are delivered online. Broadband Internet connectivity may be required for these software applications and materials, which may be a problem in developing countries. An alternative to Internet access may be to deliver these applications by installing them on the computer or servers or delivering on CD-ROMs and other devices.

In Malaysia, a large number of interactive courseware had been produced, customized to the Malaysian culture and context, and verified by teachers during the Smart School Pilot Project and the Teaching of Mathematics and Science in English program (Alias et al. 2013). These materials were supplied to all schools on CD-ROMs since 2005 as part of the Teaching of Mathematics and Science in English program to avoid online delivery and lack of Internet connectivity. However, currently e-materials are also provided and hosted on online platforms for schools to access when Internet connectivity was available. In addition, teachers are also required to develop their own instructional materials on the “sites” in the FrogVLE. This variety of delivery methods ensured that the affordances of the software applications and instructional materials were *transferable* to different contexts.

Social Effect on the Users

The next consideration is whether there is *viability of the technological innovation* (Lubin 2018). In addition to the technology (hardware and software) provided, the users and society in general need to be considered. In implementing the technology solution in the developing country, policy-makers and managers would need to consider the social effect on students, teachers, and administrators as a result of the innovation. Would the social effect, and the acceptance level, be the same as originally envisioned when it was implemented in the developed country?

Managers implementing computers in education programs in developing countries need to consider the viability of the program before implementation. For example, research has shown that when only instructional materials such as textbooks are provided, these do not necessarily improve learning (Glewwe et al. 2009; Kremer et al. 2013; Pedró 2018). Instead, when instructional materials provided are supported with an applicable instructional model and a teacher training program, it becomes more effective (Pedró 2018). Hence, when computers in education are implemented in

developing countries, managers need to consider having an appropriate teacher training program to develop human capacity. This is discussed further in the later section.

In addition to providing training programs for teachers, consideration on whether these materials are suitably adapted to the culture, morals, customs, and perhaps even language of the developing country. If the technology innovation is not suitable for use in the target culture of the developing country, it may not be accepted well by teachers and parents. As an example, the Ministry of Education Malaysia has attempted to introduce mobile phones for teaching and learning in schools in 2005 and 2017. However, there have been objections from teachers on the use of this device in school as it was claimed that disciplinary problems would arise. Hence, the *viability* of the use of this device for teaching and learning was in question, and innovation related to this device might not be accepted by teachers.

Hence, when resources and computers are provided, they can only have an impact on education when there is a commitment from teachers and parents on the usefulness of the resource and the technology. In addition, teachers need to believe that the resources can be adapted to the individual student's level and result in changes in student's learning experience (Pedró 2018). Managers in developing countries need to consider the development of human capacity for the acceptance on the use of computers in education. The acceptance and support for building human capacity are discussed next.

Building Human Capacity

The *viability of a technological innovation* depends on the human factor. Teachers are most directly involved in the instructional change when computers are used in education and they can most likely determine the success or failure of the program. However, teachers can only perform at their best when instructional leaders in their school support the change. Hence, developing human capacity among teachers and

instructional leaders is important for the viability of the program.

Pedagogy Matters

When computers are used for education, the way teachers teach and the instructional materials which are used may need to change. The traditional forms of teaching differ from a blended or online model of instruction using computers. Hence, the instructional role of the teacher and the pedagogy, which is the practice of teaching employed, may need to change.

In some computer in education programs, teachers are provided with instructional materials, and hence, teachers need to plan their teaching so as to provide meaningful educational experiences for their students learning. However, when implementing a new technological innovation, does it make provisions for teachers to be well trained in the program? Teachers in developing countries may not have been trained to integrate technology in their instruction as they may not have had sufficient reason for this form of training, seeing as schools were not provided with such equipment. As a result, these teachers, when confronted with computers and electronic instructional materials, do not know how to best use these materials and feel at a loss when using them (Pedró 2018). Hence, managers need to ensure that when a computer in education program is implemented, teachers are provided sufficient training in the pedagogies for use with computers.

Providing the appropriate training ensures effective use of technology. McEwan (2015) provides empirical evidence that in developing countries, effective use of technology for teaching is accompanied by appropriate teacher training. This would ensure that students receive the best impact on their learning. Hence, when implementing computers in education programs, the right pedagogy which would most help teachers in using the new technology needs to be identified (Pedró 2018). However, applying the suitable perspective of pedagogy also depends on which applications and instructional materials will be used.

There are several perspectives of pedagogy which can be taken when using computers in

education. The behaviorist perspective assumes the transmission model of instruction and uses the *stimulus-response* interaction, with teacher questioning and students answering, accompanied by *immediate feedback* for reinforcement (Bower 2017). This perspective seemed to be used in many learning courseware in the Malaysian context, where a mastery learning approach seemed to be used. On the other hand, the cognitivist perspective looks at the mental processes in forming and reorganizing knowledge, using an information processing framework (Bower 2017). Some courseware also use this approach as learners are required to compare, identify similarities and differences, and make inferences from the information presented.

On the other hand, the constructivism perspective is based on the individual actively constructing his own knowledge, through processes of *assimilation* and *accommodation* (Bower 2017). The role of the teacher in the constructivist learning environment is to design learning environments for the learner to discover principles (Bruner 1990). The social constructivist perspective extends on the constructivist perspective by including cultural and social elements in the learning process (Bower 2017). Learning is facilitated through discussions and negotiation as the teacher scaffolds the learner toward achieving expertise (Vygotsky 1978). In the Malaysian context, the FrogVLE enables a collaborative form of learning using online discussion in a social constructivist perspective.

Connectivism is another perspective where learning knowledge is a networked phenomenon, and to be effective, the learning networks need to be decentralized, distributed, and dynamic in an organic and rhizomatic way (Bower 2017). Connectivist pedagogies help people develop digital and critical literacies needed to survive in a networked world (Siemens 2005). There are many specific pedagogical approaches which fall under the above perspectives, and have been used with technology, and may be beneficial for teachers in working with computers such as collaborative learning, problem-based learning, inquiry-based learning, constructionist

learning, design-based learning, and game-based learning (Bower 2017). The teacher would need to consider the instructional materials to be used when implementing computers in education program and to use the appropriate pedagogy for designing the learning environment suitable for his students.

In Malaysia, teacher training had focused on constructivist and inquiry-based learning in 1996, before deliverables of the Smart School Pilot Project was deployed in schools. The Smart School Conceptual Blueprint indicated that a variety of resources could be used for learning, including realia, and stressed on encouraging students' multiple intelligences (Ministry of Education Malaysia 1997). However, when the Smart School Integrated Solution was deployed with instructional materials (courseware) for self-paced, self-accessed, and self-directed learning, there was still some ambiguity on the use of these materials. One reason might be because the pedagogical perspectives in some of the courseware differed from teachers' perspectives. Another reason was that teachers who were originally trained for the pilot schools had transferred to different schools when actual deployment was done in 2000. Hence, continuous retraining efforts had to be conducted for more effective implementation.

Managers of computers in education program need to be aware of such issues regarding training. Teachers should be provided training in the pedagogies for computers in education and be exposed to instructional models which can be used for teaching. At the same time, efforts for retraining and upskilling teachers from time to time need to be provided.

Acceptance of New Technologies

Introducing an innovative computer in education program may require teachers to acquire new pedagogies. Teachers no longer need to be traditional transmitters of knowledge but instead are required to be facilitators for students' learning. Some teachers may find this change to be too abrupt and perceive the introduction of this change as a threat to their existing practices. Managers of computers in education program

need to be aware of this perception among teachers and adopt the right attitude to address this change.

As mentioned earlier, the viability and success of a program depend on the teachers who are the implementers and would ensure that successful learning environments could be designed. However, many a time teachers seem to be at the receiving end of the technology and have to implement the program without assistance and support given for the use of the technology. Coupled with the lack of confidence and belief in the technology, teachers who are not convinced on the usefulness of technology would reject it.

The theory of reasoned behavior notes that teachers' beliefs would motivate and influence the attitude toward the technology and the intent to use the technology (Davis et al. 1989). Hence, the perception of the ease of use of the technology and the relevance of the technology to solve the problem would determine whether teachers make use of the technology.

This means that for teachers to perceive the technology as *easy to use*, they should have sufficient training in the use of the technology itself. This means developing professional or personal skills such as having a technical command of the computer and being able to set up the computer for use (Pedró 2018). Hence, managers would have to determine that sufficient technology skills are developed among teachers involved. Teachers who have technology skills are more likely to perceive the innovation as *easy to use*.

Secondly, is the *relevance* of the technology to address instructional problems. In order for teachers to perceive the relevance and validity of the solution, teachers should be informed and made aware of the benefits of implementing the innovation. For computers in education program, benefits which may arise are the increase in students' motivation and improved academic performance (Pedró 2018).

Managers need to ensure that instructional leaders share the vision of the change that the innovation would bring and would be able to communicate this vision and lead other teachers toward successful implementation. The

instructional leader who can be the school head or a technology leader in the school needs to continuously communicate the goals of the program and the change efforts to the entire school community so that they are made aware of the benefits of the change (Abdullah et al. 2013). Only in this way, the school community would develop the right attitude toward the change. The vision of the innovation should also be communicated to parents so that they would be aware of the innovation and support the implementation.

Managers should ensure that there were suitable supports for teachers, both in using technology and in addressing change. Communities of practice in the use of technology and for teaching with technology can provide support when an innovation is implemented.

In conclusion, development of human capacities has to consider the teachers' needs. Teachers would be more convinced if the innovation was able to show a long-term effect on the students' results and to make teachers' work more efficient (Pedró 2018; Van Velzen 2013). Teachers also needed to see a lot of different situations in which students were using the particular innovation and methodology and also needed comparisons to be made with other methods currently being used (Pedró 2018; Van Velzen 2013). Only when teachers had the right attitude toward the innovation and were convinced of the benefits of the innovation, there would be more chances of viability of the innovation (Pedró 2018). In order to support teachers' implementation of the innovation, there has to be the right policies in place so that teachers are aware that what they are implementing meets the desired vision of the organization.

Policies

The World Bank (2012) notes that developing countries should build policies to strengthen skills and competencies among the population, to build capacity, and to improve the technological infrastructure and services, which include broadband connectivity. The following discussion builds on policies related to building the skills

and competencies among teachers to teach in the new instructional environment and policies related to infrastructure development.

The Instructional Environment

The use of computers in education changes the teaching and learning processes. In order to support these changes, there will need to be additional policies in place, or replacement of current policies, so as to ensure the vision of the innovation will be maintained. Salas-Pilco and Law (2018) reviewed ICT policy initiatives in small developing countries and found that most of these countries had policies which were stated as simple strategies, programs, or projects rather than clearly defined, system-wide policies. A favorable ICT policy needs to be a formal ICT policy developed as part of a national plan. The implementation of the Smart School initiative in Malaysia was part of a national plan in developing the MSC nationwide. This ensured the success of the project. In addition, policies were identified in the educational system to ensure that a systematic change in policies was initiated for the implementation of the Smart School Integrated Solution. Policy changes included the acceptance of online attendance, lesson planning, reporting, and assessment.

Salas-Pilco and Law (2018) identified that most of the policies of small developing countries focused only on integrating ICT into the curriculum for all subjects. In addition, the four different aspects of ICT in education that was considered were for ICT in the curricula, teacher training, school infrastructure and connectivity, and development of digital resources. The countries reviewed did not have a separate subject for ICT.

Hinostroza (2018) outlined the challenges which developing countries need to address in the policies on integrating ICT into the curriculum. He states that the policies would need to consider the definition of the set of digital skills that teachers and students need to acquire, the integration of these skills in the curriculum, strategies to ensure that teachers and students develop these skills, and the pedagogical methods that take advantage of these skills in the teaching and learning of traditional subject

areas (Hinostroza 2018). Hence, managers should consider that policies to address these issues need to be defined.

Teachers require new competencies to address the change that teaching with computers brings. Hinostroza (2018) states that challenges in teachers managing the integration of computers for learning and managing the learning take place both inside and outside the classroom, as well as ethical and legal issues regarding the use of online resources among students and teachers. For this purpose, teachers require a new set of digital competencies such as the UNESCO (2011) ICT Competency Framework for Teachers. As the curriculum and the use of digital contents and tools may also need to change, relevant policies need to be put into place to assist these changes (Hinostroza 2018). The implementation of computers in education should not be just adopting the technology for modernization of education but for an overall systemic change in the education system.

Infrastructure Development

ICT has the potential to develop the capacities of the workforce in developing countries. However many of these developing countries do not have a strong technological infrastructure in terms of reliable electricity supply and Internet connectivity (Salas-Pilco and Law 2018). However, the cost of providing for ICT infrastructure is high.

Developing countries may need to look at new possibilities of providing infrastructure for computers in education. Salas-Pilco and Law (2018) suggest the following: (1) establishing smart partnerships with organizations, which may be private, either international/regional, and also with other related institutions to implement computers in education programs, (2) establishing leverage on international support, and (3) establishing collaborations between countries.

Among the organizations which have provided funding for improving capacity in ICT are UNESCO and the World Bank, and private companies such as Intel® and Microsoft® have also provided support in providing training materials and developing capacities among teachers

for computer in education (WBG 2012). Managers of computers in education program should negotiate for assistance and support from these organizations.

Another consideration for building infrastructure within a developing country is for existing companies in the developing country to have links with technology firms in developed markets. This is so that talent and infrastructure can be built in the developing country, while the firm in the developed country can grow their businesses internationally (WBG 2012). Other voluntary collaborative communities can be sourced out to develop and support existing networks in the developing country. One such community is MobileMonday, an open community platform of mobile industry visionaries, developers, and influential individuals, which originated in Helsinki (WBG 2012).

Strategic public investments in the development of ICT infrastructure should be considered. Many developing countries may lack private investment, despite having sound policies and regulatory frameworks. Hence, developing public-private partnerships (PPPs) for providing high-speed Internet to improve global broadband connectivity can benefit the country (WBG 2012). PPPs, when tailored to the country's context and ICT sector specificities, are a practical solution to building the infrastructure.

Managers of computers in education program need to be innovative in their approach in providing the infrastructure which is needed in small developing countries. Ensuring that the proper policies are put in place can ensure the development of the country can be leveraged on these policies.

Conclusion

Computers in education programs can be employed for building human capital in ICT. However, implementing such programs cannot be undertaken without proper consideration and planning. The managers of computers in education programs in developing countries need to consider providing for inclusive programs to

reduce the digital divide among the different levels of society. The high cost of investment of an inclusive program must be balanced with the benefits for the country. However, care must be taken before adopting technologies and programs which have been implemented in a developed country, because issues such as the transferability of the affordance of technology and the social effects for the viability of the innovation need to be considered. Building human capacity is important for the viability of the innovation, and training for the appropriate pedagogy, technical skills, and acceptance of the technology needs to be provided. Policies that are in place for designing the instructional environment using ICT and developing the infrastructure can provide leverage for the success of computers in education program. Hence, managers have to ensure that proper planning and thought go into the implementation of computers in education program, so as to be successful and able to contribute to the productivity and economic growth of a developing country.

Summary

The information communications technology (ICT) industry holds the promise of improving a country's productivity and economic growth. Hence, developing countries have been jumping on the bandwagon, implementing computers in education programs for building human capacity in ICT. However, implementing computers in education requires significant amount of planning. Policy-makers and managers would have to consider several issues. One issue is to ensure that such programs are inclusive for all levels of society, primary and secondary schools as well as rural and urban areas. This is so as to reduce the digital divide among these levels of society. However, the cost of investment of inclusive computers in education program is high. One way to reduce costs is to adopt programs which have already been implemented elsewhere, perhaps in a developed country. However, issues like the transferability of the affordance of technology and the social effects for the viability of the innovation

need to be addressed. Building human capacity for using the innovation may be the solution for ensuring the viability of the innovation. Training has to be provided for the appropriate pedagogy and technical skills, while awareness of the benefits of the technology and the ease of use and acceptance of the technology hence influence the intention to use the technology. Strong policies would also have to be put in place for designing the instructional environment and developing the infrastructure in the developing country to ensure the success of computers in education program. In describing these issues, Malaysia is used as a case for the implementation of their computers in education program, the Smart Schools.

Cross-References

- ▶ [Adoption of Innovative ICT-enabled Systems for Analysis- and Intuition-styled Teachers in Primary Schools](#)
- ▶ [Computers and Educational Improvement](#)
- ▶ [Decision Support Systems and Knowledge Management in Education](#)
- ▶ [Different Methodological Approaches to Considering the Adoption of ICT](#)
- ▶ [Educational Support on Computing and Informatics for Disadvantaged Groups, An Empowerment Perspective](#)
- ▶ [Human, Social, and Ethical Aspects of Information Technology Management Systems](#)
- ▶ [Information Technology for Local Education Authorities and School Districts, Use of](#)
- ▶ [IT in Educational Institutions, Planning and Development of](#)
- ▶ [Leadership on Information Technology in Education](#)
- ▶ [MOOCs, Teacher Professional Learning and Deep Learning Conversations](#)
- ▶ [Policy Rationales and Integration Rationales, Implications for Subject Area Teaching](#)
- ▶ [Restructuring Teachers' Knowledge for Teaching With Technologies with Online Professional Development](#)
- ▶ [Situative Perspective and Determinants of Technology Acceptance in Educational Technology](#)

- Support for School and Institutional Improvement and Accountability
- Teacher Education and Professional Development for Technology Integrated Teaching
- Teacher Education, Thinking About ICT

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Computers in Primary Schools, Educational Games

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Synonyms

Digital game-based learning; Edutainment;
Game-based learning; Game-based learning environment; Learning by gaming

Introduction

This entry is focused on the use of digital games at primary school level. In particular, the entry briefly presents different modalities in which digital games can be introduced and considers, in particular, their role in stimulating and assessing students' transversal skills, that is, those cross-skills that are at the basis of the learning of many different disciplines.

Early activities in this field appear to be particularly effective, especially if we consider that thinking skills develop slowly and that primary school offers usually a more flexible context, both as far as curricula constraints and time organization, to introduce nontraditional activities. Logic and spatial reasoning skills are in particular considered making reference to research studies performed at the Istituto Tecnologie Didattiche (Institute of Educational Technology) of Consiglio Nazionale delle Ricerche the Italian National Research Council.

Games and Education

Play has always been considered an important part of children's personal and social development. Psychologists have long stressed the critical role of play in childhood development (Bjorklund and Pellegrini 2010). Today, play also encompasses the sphere of digital games. The present generation of children and youngsters has grown up with digital technology and, for many of them, digital games represent an important – if not the chief – form of play. Over the years, numerous research studies have been carried out that point to the strong potential that digital games offer for learning. At the same time, their adoption in Europe's schools has been growing steadily (Hailey et al. 2011; Boyle et al. 2015).

Educational software applications – namely those designed with the express intent of fostering knowledge acquisition through interaction with learning contents – have increasingly made use of gameful strategies and elements. Partly as a result of this, digital games have gradually found their way into primary and secondary school classrooms, where they have been shunned by some teachers

but welcomed by others (Sandford and Williamson 2006). The main obstacle to the integration of games into compulsory school curricula seems not to be the negative attitudes of teachers, schools, or parents, but rather the lack of suitable equipment and adequate teacher training and effective methodologies to integrate them in the class learning activities. A key condition for take up is the realization that the introduction of digital games must be intertwined with mainstream teaching practices and specific educational objectives; digital games must be seen as a further way of responding to the diverse range of needs that teachers have to address (Felicia 2009). They should be part, at least at primary school level, of the learning environment as well as a variety of tools and learning materials.

A wide spectrum of game types is available for learning purposes, including roleplays, adventures, puzzles, serious games, etc. (Schiffler 2006). These also feature a range of different strategies such as free exploration/navigation, question and answer routines, artifact making, etc. Some games adopted in educational contexts are explicitly designed to support the pursuit of learning outcomes (Garris et al. 2002). Others originated purely for entertainment purposes but are applied for teaching/learning (Benigno et al. 2010) or for rehabilitation (Caruso et al. 2017).

The first and most commonly highlighted potential of games is that of boosting student motivation (Connolly et al. 2007). Games offer stimulating experiences that can trigger players' intrinsic satisfaction and thus keep them motivated. Various authors (De Aguilera and Mendiz 2003; Gee 2003; Prensky 2003; Bransford et al. 2000; Caponetto et al. 2014) point to the appeal of games for motivating both young and adult players, as well as support for exploration and imagination, with opportunities for investigation, reflection, and learning (Silveira et al. 2011).

By the same token, various studies demonstrate that tangible benefits for learning need to be sought well beyond simple motivation (Whitton 2010).

In an article from the American Psychological Association (Granic et al. 2014), the authors identify four kinds of beneficial impact games can have on children: cognitive, motivational, emotional, and social. This assumption, of course, is to be further

specified considering the different typologies of games that can be used to pursue educational objectives. When referring to the use of digital games, in particular, the analysis of the efficacy for learning of their use is to be investigated in specific contexts and against clearly defined objectives and situations (Amory et al. 1999).

For example, some types of digital games are suited for fostering students' problem-solving abilities (Whitebread 1997; McFarlane 2014), for promoting creativity (Ott and Pozzi 2011), and for supporting decision-making processes in both children and adults (Charlier et al. 2011). Many authors maintain that playing digital games can have a significant impact on some children's basic cognitive abilities like, for example, reasoning and logic abilities (Bottino and Ott 2006) or computational thinking (Kafai 2006). The impact of the use of digital games on students' performance in school disciplines such as mathematics has also been investigated with positive results (Bottino et al. 2007; Freina et al. 2017b).

Considering in particular the development of basic cognitive skills, as an example, in the following reference is made to a number of research studies performed at the Institute of Educational Technologies of the Italian National Research Council which have investigated the role that digital mind games can have in stimulating and assessing primary school students' logic and spatial reasoning skills. Thinking skills and, more specifically, logic and spatial reasoning skills have been in particular considered.

Digital Games in Primary School

Addressing the role that digital play can have in primary school education requires a perspective that helps teachers see how children's digital play supports the development of crucial basic skills, such as reasoning, critical thinking, and problem-solving skills, that contemporary research identifies as necessary for supporting young children's engagement in digitized communities (Cope and Kalantzis 2009). These skills are at the basis of the learning of many different disciplines (Cotton 2001; Zohar and Dori 2003).

Early activities aimed at fostering and stimulating such skills appear to be remarkably effective, especially if we consider that thinking skills develop slowly (King and Kitchener 1994; Edwards 2013) and that primary school offers usually a more flexible context, both as far as curricula constraints and time organization, to introduce not traditional activities. This is particularly true if a game-based approach is chosen.

Different modalities can be adopted to integrate digital game playing in primary school education: use games explicitly implemented with educational purposes in mind; selecting and using, for a significant period of time, games that are not built for education (like puzzles or mind games) to foster the development of specific and clearly identified abilities; and introduce children to the building of digital games through programming. This last opportunity can be carried out both by means of a programming environment expressly developed for children or using games that allow children to act also as "builders" instead only as "player." Consider, for example, Minecraft (Ekaputra et al. 2013), a sandbox digital game where players can interact with a variety of different blocks in a 3D virtual world to create virtual houses and buildings.

The development of abilities by means of digital games (whether they are explicitly developed for this purpose or that entertainment games are used) requires to carefully identify the kind of abilities to be developed and, consequently, the types of digital games best suited for this. Consider, for example, the case of mind games that deeply require the enactment of thinking and reasoning skills (Prensky 2003). These differ from brain training games in that they usually call on the player to work out and apply problem-solving strategies so as to complete the game (Bottino et al. 2013b). Even if it is generally suggested that they can be used in schools to foster learning (Vaegs et al. 2010), they are not frequently studied from the point of view of learning outcomes (Facer et al. 2007) and few studies investigate the specific cognitive abilities they involve (Milovanovic et al. 2009). The research studies performed at the Institute of Educational Technologies highlighted the pedagogical potential of mind games to support and foster reasoning and visual spatial skills and

showed that their use under certain conditions may also have a positive impact on school performance in curricular subjects such as mathematics.

In such studies, the use of mind games to support learning is faced according to a number of different but complementary perspectives:

- Analysis of the cognitive skills involved in the use of a selected number of mind games (Bottino and Ott 2006; Bottino et al. 2012).
- Development of a methodology, based on the use of mind games, to assess the identified reasoning skills; analysis of the results obtained in applying such methodology to a sample of primary school children (Bottino et al. 2014).
- Examination of interface and game mechanics features that make mind games more or less suited for developing logic and reasoning skills (Bottino et al. 2009).
- Investigation on the effects of the appropriate use of selected mind games towards students' school performance, behavior, and attitudes (Bottino et al. 2007).
- Analysis of the impact of training spatial abilities with a number of selected digital games on mathematics performance of primary school students (Freina et al. 2017b).
- Investigation of specific characteristics of games on performing basic cognitive tasks, in particular investigation of the relationship between immersion in virtual reality, presence, and performance in spatial reasoning tasks (Freina et al. 2017a).

In order to provide some examples, two specific projects will be shortly outlined in the following.

Stimulating and Assessing Logical Reasoning and Problem-Solving Skills

The use of digital mind games to evaluate logical reasoning and problem-solving skills in primary school children was at the basis of the *Logivali* project that investigated also the most appropriate affordances that the games offer for evaluating and fostering children's solution strategies (Bottino et al. 2009). The games selected for the project involved only minimal maths or language

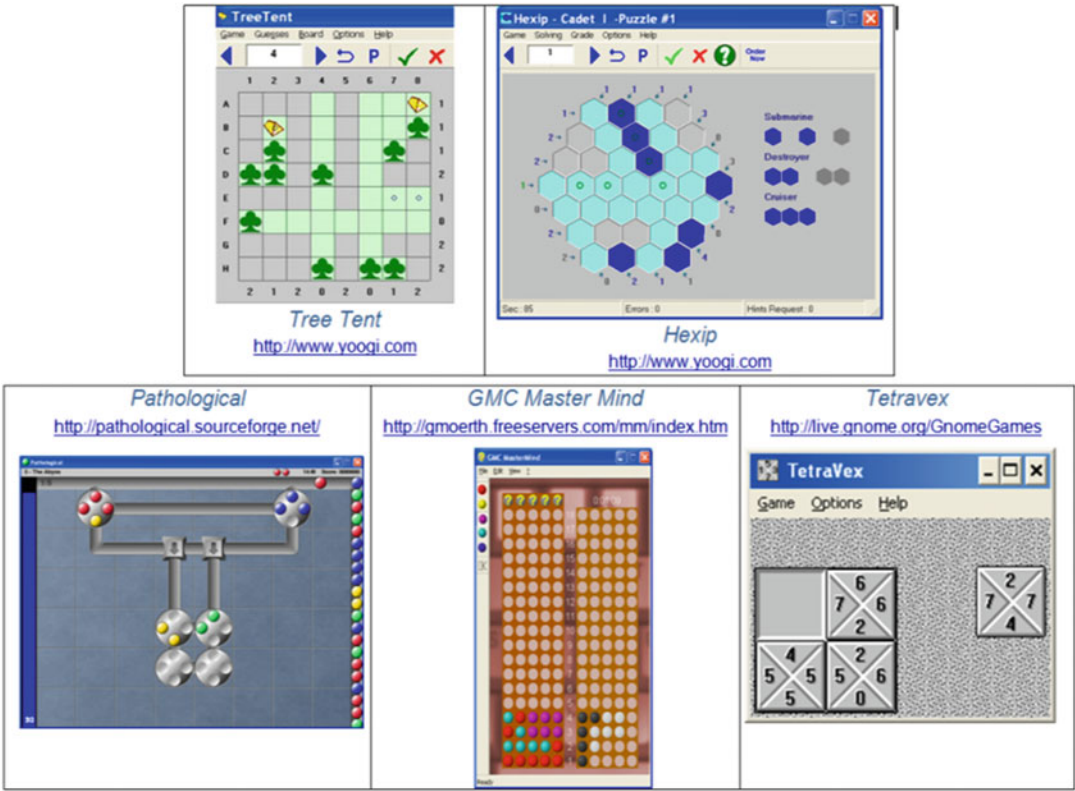
skills and the element of chance was marginal. Moreover, the games featured no strict time limits so that the pupils could think calmly and focus on the outcome itself rather than on how fast they managed to reach it. Feedback provided was another of the features considered in the choice of the games. Figure 1 shows screenshots of the games selected.

A test based on the use of the above-mentioned mind games was developed and tested with 26 fourth and fifth grade classes in Italian primary schools involving a total of around 500 children, who played the games individually and, at the conclusion of the game sessions, underwent the *Logivali* evaluation test. This test evaluates different abilities involved in solving the games: knowing the rules and being able to apply them in gameplay situations; being able to make an inference based on one, two, or more given piece of information or constraints posed by the game; being able to judge whether the information available at a certain point of the game makes it possible to ascertain the correctness of a given move or configuration; and being able to apply previous reasoning (at any level) in order to complete a game. In addition to the test validation activity, test results were also compared with children's school marks. This comparison revealed a general correlation between the children's school performance and their capacity to solve mind games (Bottino et al. 2013a).

Developing and Exercise Visuospatial Abilities

The "*Eyes on Me*" project was organized to support the development and consolidation of visuospatial abilities in students of the last 2 years of the Italian primary school, with the hypothesis that such a training would have a positive impact on their performance in mathematics. Twenty game-based training sessions were set up along the whole school year, involving two experimental classes, while another two classes served as control group. Students' mathematical abilities were measured at the beginning of the project and at the end using a math test that had been standardized on the Italian population.

Several game apps and computer games were accurately chosen according to their characteristics



Computers in Primary Schools, Educational Games, Fig. 1 Screenshots of the five mind games used in the *Logivali* project

in order to focus on the training of visuospatial abilities. At each meeting, students played freely, choosing between a restricted set of games focused each time on a specific ability. The games were mainly of the following types:

- Visual memory games which included activities like remembering a list of objects, the location of items on a 2D board, etc.
- Movement and rotation of 2D objects (e.g., jigsaw puzzles, tangram, etc.).
- Definition of a path on a 2D plane (e.g., maze-based games).
- Games in which an image or a solid is reflected as on a mirror (axial symmetry).
- Movement and rotation of 3D objects using games in which the player had to follow a path in a 3D structure. The interface of the games allowed to turn around the structure and to analyze it from different perspectives.

- Spatial Perspective Taking games. Spatial Perspective Taking (SPT) is the ability to predict what a scene would look like from different perspectives. In particular, the “In Your Eyes” game was used. This is a virtual reality game developed expressly for the project.

Results show a statistically significant improvement of mathematical performance in the experimental group when compared to the control one, confirming the initial hypothesis according to which having good visuospatial abilities has a positive influence on school achievements in mathematics (Freina et al. 2017b).

As far as the use of virtual reality digital games, the project also investigated if, and to what extent, immersion actually supports better performance in spatial perspective taking considering it as an embodied process (Surtees et al. 2013). To this end, the game “In Your Eyes” was developed in

three different versions, each corresponding to a different level of immersion in a virtual world: completely immersive, using Oculus rift; semi-immersive, without head-mounted display; and non-immersive. The project investigated if there is a correlation between the immersion level of the game and performance in SPT tasks. Results show that, while having the possibility to move freely in a virtual environment (immersive and semi-immersive versions) helps to have a better performance in the task, the complete immersion using a head-mounted display does not have a significant impact (Freina et al. 2017a) and can give also some drawbacks (e.g., sickness issues).

This project provide an example in which both on-the-shelf games and ad-hoc developed digital games were used with the objective to improve visuospatial abilities in primary school students.

Methodological Issues

The above briefly outlined examples and the overall experience in the field allow to sketch a possible methodology to follow, entirely or partially, when planning the introduction of digital games in primary school. Simplifying, such introduction should be designed taking into consideration the following aspects: the objectives to be pursued (e.g., the skills to be trained); the methodology to be followed (e.g., the tools available, the organization of the class work, the time allocated for each game sessions, etc.); the games to be used (selecting them considering the interface and game mechanics features of the games in relation to the objectives to be pursued); the possible effects on students' school performance, behavior, and attitudes; and students' general acceptance and enjoyment.

As far as this last aspect, from the experiences performed emerged the fact that, in general, the involvement and the interest are higher with those games that required a more active participation from the children (as it was the case, for example, for the Minecraft contest). This suggests that it would be interesting and fruitful to promote not only game playing but also their creation and development.

As the matter of fact, one can play by the rules or with the rules, in the sense of building a new game. Digital games are largely an example of playing by the rules, but games creation too can become a very valuable educational activity, able to trigger students' transversal skills, such as reasoning abilities, creative attitudes, and computational thinking (Bottino and Chiocciariello 2014). Specific environments to support games building activities are available and there is an increasing interest in their educational use. Kodu is an innovative environment for the creation of video games inspired by robot behavior programming (Coy 2013). Scratch, a visual programming environment where the instructions are assembled like LEGO building blocks (Resnick et al. 2009), is another popular environment for building digital games. Kafai and Burke (2016) argued that student-designed games teach not only programming but also academic subjects and transversal basic skills such as collaboration and team working. However, they do not suggest a shift to game making from game playing but rather argue for a more comprehensive, inclusive idea of game use in education in which both making and gaming play are considered.

Conclusions

Learning by playing is probably the ideal condition of education. The widespread diffusion of digital games and serious games makes it necessary to reflect on their educational use at all levels including primary education. Many research studies has pointed out that playing digital games it is not only enjoyable and motivating for children but can have also a significant impact on their cognitive abilities and can support the development of skills that are not specifically related to a particular disciplinary field or technical ability but which are at the basis of learning in most school subject areas.

For example, a game-based learning approach is an excellent springboard for addressing problem-solving in primary school, helping learners to reflect and reason in a systematic and structured manner. The use of mind games can help young learners acquire and/or strengthen reasoning skills that can be gainfully employed in problem-solving

strategies based on logical thinking. Games creation and coding can become too a very valuable educational activity, able to trigger students' problem-solving skills, creative attitudes, and computational thinking. Playing or making games can also deliver a clear message to learners that in order to obtain good results, they need to apply themselves with concentration and persistence.

However, the effective use of games at primary school level needs to be planned against specific and well-identified objectives and the games to be used are to be selected accordingly.

Rapid evolution in the digital games field, including development of new and attractive play modes like those based on virtual and augmented reality, is continuously broadening the range of products available. Consequently, teachers need to be informed not only about the theory, potential, characteristics, and limitations of these tools but they also need to possess the methodological capacities required to select appropriate games, and design and implement rich, well-structured learning activities featuring the use or the creation of digital games.

As experience has shown, the design of such learning activities should be done considering the demands and needs of both the class and individual learners, taking into account a number of aspects such as those that follows:

- To choose the games to work with in an effective manner by evaluating how the games fit the learning objectives that have been identified and by understanding the games mechanics and interface features (appeal, functionality, and usability) at play.
- To choose games that are relatively independent from specific prerequisites in curricular school subjects.
- To accurately tune the progression of the difficulty level.
- To appropriately calibrate the level of assistance to offer to each single student so as to trigger reasoning and strategic thinking and adequately support students' motivation and engagement.
- To consider that the use or the creation of games can prove useful if it is not sporadic

and planned on a short-term basis but if it is incorporated in activities that cover a medium/long term period of time.

The experience gained in these years in research studies involving the use of digital games supports the assumption that early and appropriately designed educational interventions involving engaging game-based activities can positively impact the development of children's cognitive basic skills and this can have an impact on students' school performance (e.g., in the areas of maths and logical reasoning) as well on students' learning attitudes and behavior.

Cross-References

- ▶ [Algorithmic Thinking in Primary Schools](#)
- ▶ [Digital Storytelling, Information, and Education](#)
- ▶ [Game-based Learning](#)
- ▶ [Games, Simulations, Immersive Environments, and Emerging Technologies](#)
- ▶ [Gamification](#)
- ▶ [IT in Educational Institutions, Planning and Development of](#)
- ▶ [Mobile Learning](#)
- ▶ [Technology Enhanced Learning](#)

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Computers in Secondary Schools

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Synonyms

Computer science education; Computing education; Didactics of informatics

Computers in secondary schools have a long tradition, approximately 45 years (Tatnall: [Beginnings of Computing in School Education in Australia](#)). A milestone was the presentation of Andrei Ershov “Programming, the second literacy” in 1981 at the third IFIP World Conference on Computers in Education (WCCE) (Ershov 1981). Since then experts of computer science education are discussing which programming languages are appropriate to learn and to teach this “second literacy.” There are five entries in this encyclopedia to enlarge upon this topic: programming and coding, programming languages for secondary schools, Python, Java, and Pascal.

The next step was the development of an own subject for computers in secondary schools. The subject was called “computer science” or “informatics” or “computing.” All international computer societies supported the discussion process to establish curricula for this new subject and for the related teacher education. The “Association for Computing Machinery (ACM)” started in 1993 with such a curriculum, and for a long period, the “Model Curriculum for K-12 Computer Science” of ACM published in 2006 influenced the “didactics of informatics” worldwide (ACM 2006). We summarize under “didactics of informatics” all research and teaching activities which aim to improve the learning and teaching process in the subject “computer science” or “informatics” or “computing.” There are six entries in this encyclopedia to enlarge upon this topic: Teaching about computing (computer science or other titles), Challenges of

teaching computer science, Competency model for teaching computer science, Computer science standards at schools, Curricula in computer science, and Value of teaching computer science.

Over the years an international research community emerged. At universities the teacher education of informatics required professorships of didactics of informatics. Therefore far more assistant researchers started their work in this field. In 2017 the 11th IFIP World Conference on Computers in Education (WCCE) was commenced with a doctoral consortium (IFIP-TC3 2017). The paradigm shift to a learner-centered and an outcome-oriented view on learning processes has been influenced by discussions and ongoing research in different areas of didactics of informatics. There are five entries in this encyclopedia to enlarge upon this topic: Computer science education based on fundamental ideas, Teaching methods of computing education, Informatics problem-solving, Learning from gifted peer, and Practices of computing education.

Especially as a result of the Bologna Process and the OECD Program for International Student Assessment (PISA), the development and assessment of educational standards became a high-level objective in the educational system. Standards for the major school subjects, like mathematics, natural sciences, and the first language, were developed for different levels of education. In informatics the development of educational standards is not as advanced as in those main school subjects. Nevertheless, these standards weren't based on an empirically proofed competence model for informatics.

Therefore researchers in the fields of informatics and psychology started the project MoKoM (Modelling and Measurement of Competences in Informatics) funded by the German Research Foundation (DFG) from 2008 to 2015 to develop a competence model and to measure related competences of senior class students. The research project focused on two specific domains: informatics system comprehension and object-oriented modeling. Domain-specific competence models with regard to their internal structure and different competence levels are used to define educational

standards and thereby contribute to the development of curricula, and they enable the measurement of competences and learning outcomes in diverse educational settings (Neugebauer et al. 2015).

The research project KUI (Competences for the Teaching of Informatics) cooperated partners from the universities of Munich, Paderborn, and Siegen. The project was funded by the German Federal Ministry of Education and Research (BMBF) from 2012 to 2015 to identify competencies that are particularly needed to teach informatics with the focus on three categories: subject matter competencies, pedagogical content knowledge (PCK), and non-cognitive competencies. As result a category model of the PCK competencies was developed through a content analysis of recent curricula of universities and an empirical verification by interviews of informatics teachers (Margaritis et al. 2015).

The collaborative learning with school Intranets (Schubert 2001) was another focus of didactics of informatics. There are two entries in this encyclopedia to enlarge upon this topic: "Mobile computing and mobile learning" and "Social media and networks as digital instruction and learning platforms". Didactics of informatics supported a new qualification and certification for specialist ICT teachers (Schubert 2003). There are six entries in this encyclopedia to enlarge upon this topic: Teaching with computing, Robotics, Curriculum, IT and the school curriculum, Educational games, and Applications – word processing, graphics, and spreadsheets.

We illustrate the development of didactics of informatics with some examples. Nowadays many curricula are based on empirically proved competence models of the subject. To bridge this research gap in informatics, the MoKoM project addressed the following issues:

1. Development of an empirically proved competence model
2. Development of test instruments that are appropriate for competence measurement
3. Design and evaluation of learning environments that were proved to be of high quality through competence measurement

Scenario: "You are asked by a colleague to test his software that was developed to solve configuration problems, e.g., to set up a new car or a new computer."

Question 1: "What is your strategy of testing to solve this problem? Which aspects do you have to bear in mind?"

Question 2: "Which cognitive skills are required for such a software exploration?"

Question 2.1: "Which informatics views are important for this task?"

Question 2.2: "Which complexity would you assign to this task?"

Question 3: "Which attitudes or social-communicative and cooperative skills are necessary to accomplish this?"

Question 4: "Which differences of competence levels would you expect between novices and experts?"

Question 5: "How can you as a tester be supported by this task?"

Question 6: "Could you imagine a potential pupil's procedure to solve this problem?"

Question 7: "Which obstacles would pupils have to cope with?"

Computers in Secondary Schools, Fig. 1 Scenario on testing of unknown software and its questions (Schubert and Stechert 2010)

The research process started with a theoretically derived model. In the empirical procedure, 30 experts on informatics, with a division in 3 equal groups, were interviewed (experts in the domains of didactics of informatics, computer scientists, and expert informatics teachers).

In Fig. 1 such an interview scenario is presented.

The experts answered these questions very carefully and detailed. Each interview was recorded and transcribed. The 30 transcripts could be investigated with the qualitative content analysis according to Mayring (Mayring 2003). The result was an empirically proved competence model in the area of informatics system comprehension and object-oriented modeling.

Our aim was to measure the learning results of students. Therefore, we focus on modeling of competencies as basis of test items. Two kinds of competence models are required: a structure model of competence and a model for levels of competence. The structure model of competence contains the competencies, which are required to solve problems of specific domains. We analyzed curricula of programming with PROLOG. The students are supposed to create a knowledge base referring to a given problem. The model for levels of competence contains also a differentiation into levels. At the beginning of the course,

students are supposed to add new facts and rules, which are similar to the given facts and rules. A different level would be that students are supposed to formulate own facts and rules in the following lessons. The taxonomy of Anderson and Krathwohl could be applied to separate competencies into different levels of the cognitive process (Anderson and Krathwohl 2001).

In Fig. 2, the structure models of competence are presented for learners of PROLOG, which learned already a first programming paradigm (imperative programming or object-oriented programming):

In logic programming with PROLOG, there are three different kinds of views, namely, *3.1 Knowledge base*, *3.2 Queries*, and *3.3 Tracing*. With respect to *3.1 Knowledge base*, students are supposed to understand the internal structure of logic programming. They apply, comprehend, and develop facts and rules in a knowledge base. The *3.1.1 Structure* of the knowledge base is a main theme. Furthermore, students are supposed to understand the *3.1.2 Closed-World-Assumption* in order to analyze the facts and rules. *3.1.3 Dynamic modification* of the knowledge base needs to be discussed with the students, to make them to understand the improvement of a solution and the quality of the results.

With respect to *3.2* students are supposed to perform queries. They analyze the external

- 1 Prior knowledge for logic programming
 - 1.1 Predicate logic
 - 1.2 First programming paradigm
 - 1.2.1 Imperative programming
 - 1.2.2 Object-oriented programming
- 2 Basic competencies
 - 2.1 Programming competencies related to any paradigm
 - 2.2 Logic programming
 - 2.2.1 Application of logic programs
 - 2.2.2 Comprehension of logic programs
 - 2.2.3 Development of logic programs including debugging
- 3 Informatics views
 - 3.1 Knowledge base
 - 3.1.1 Structure
 - 3.1.2 Closed-World-Assumption
 - 3.1.3 Dynamic modification
 - 3.2 Queries
 - 3.3 Tracing
 - 3.3.1 Unification and backtracking
 - 3.3.2 Trace modus
 - 3.3.3 Box model
 - 3.3.4 Parse tree
- 4 Non-cognitive competencies
 - 4.1 Attitudes
 - 4.1.2 Expectations for Informatics Literacy and Professional Practice
 - 4.2 Social-Communicative Skills
 - 4.2.1 Cooperation & Teamwork
 - 4.2.2 Empathy: Change of Perspectives & Roles (User, Developer)
 - 4.3 Motivational and Volitional Skills
 - 4.3.1 Openness to new Ideas and new Requirements

Computers in Secondary Schools, Fig. 2 Structure model of competencies of logic programming

Your parents want to publish their best recipes in an online cookbook. They want to demonstrate the preparation of the food through videos. Your parents also have purchased a new software for editing the videos. Unfortunately, they do not know the software very well because they previously used another program, which was especially designed for beginners. But they know that the new software uses the same open-source components to de- and encode videos as the old software. According to this, which of the following statements are true?

1. Both of the programs own the option “Distort Video” that can be found under the menu point “Effects.”
2. Both of the programs can import audio files in different formats.
3. Both of the programs can import videos in the same format for editing.
4. Both of the programs can enhance the videos with effects.
5. Both of the programs support different view modes for windows.
6. Both of the programs can export videos in the same resolution.
7. Both of the programs are suitable for beginners.

Computers in Secondary Schools, Fig. 3 Task of informatics system comprehension

structure of logic programming. Students formulate queries to solve a given problem, and they should be able to predict the answer of the system. 3.1.2 *Closed-world assumption* has a strong connection with this competence.

3.3 *Tracing* combines the understanding of the internal and the external view. Students are supposed to understand 3.3.1 *Unification and backtracking*, especially intern and extern backtracking, 3.3.2 *Trace modus*, 3.3.3 *Box model*, and 3.3.4 *Parse tree* can be used to illustrate and to explore the structures and to support the competence 2.2.3 *Development of logic programs including debugging*.

The next step in didactics of informatics would be the design of tasks for students. In Fig. 3 such a task of informatics system comprehension is presented:

We created 18 tasks (test items) and tested them with 800 computer science students in German upper secondary schools (Magenheim and Schubert: [Competency Models in Computing Education](#)). The measurement instrument is now available for all teachers and researchers in the field of didactics of informatics. It covers only one part of computer science education, for all the other interesting topics (Romagosa I Carrasquer:

[Snap! Programming System](#)) are also competency models required. The examples given may encourage our worldwide research community to establish such basics for teaching and learning about computers in secondary schools.

Cross-References

- [Beginnings of Computing in School Education in Australia](#)
- [Competency Models in Computing Education](#)
- [Snap! Programming System](#)

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Computers in Secondary Schools, Educational Games

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Synonyms

[Serious games](#)

Introduction

This entry introduces educational games in secondary schools. Educational games include three main types of educational activities with a

playful learning intention supported by digital technologies: educational serious games, educational gamification, and learning through game creation. Educational serious games are digital games that support learning objectives. Gamification is defined as the use of “game design elements and game thinking in a non-gaming context” (Deterding et al. 2011, p. 13). Educational gamification is not developed through a digital game but includes game elements for supporting the learning objectives. Learning through game creation is focused on the process of designing and creating a prototype of a game to support a learning process related to the game creation process or the knowledge mobilized through the game creation process. Four modalities of educational games in secondary education are introduced in this entry to describe educational games in secondary education: educational purpose of entertainment games, serious games, gamification, and game design.

Digital Games Among Secondary Learners

Play is renowned as an essential activity for the development of a child from the youngest age; but parents and educators raise important concerns about the negative effects of digital games on secondary learners. Among these concerns, the addictive behavior in relation to massively multiplayer online role-playing game (MMORPG) is among the worst expected outcomes when adults explain their worries about digital games (Gentile 2009). Some studies have pointed that use of digital games could be a symptom of depression among young adults (Thomée et al. 2012). Using games as a way to escape or due to social pressure is also leading to higher levels of addictive uses of games; however, among the factors which do not seem to be linked with the use of games is the parental control (Giles and Price 2008). While the general conception of digital games is based on entertainment, teenagers and young adults also have expectations about the use of gender affects in the pedagogical expectations on digital game-based learning (DGBL), which differs according to their gender; Karakus et al. (2008, p. 2522)

observe that “female students expect games to have instructive elements, while males desire elements that are entertaining, competitive, and multi-player.” In digital games, male player shows higher skills and time spent in secondary education (Dindar 2018) and high school (Chou and Tsai 2007). The representation of age and gender differences in the use of (serious) games leads to stereotypes that are overcome by recent studies on the diversity of playing activity across genders and ages (Loos and Zonneveld 2016).

Educational Serious Games (ESG) in Secondary Schools

Playing is often perceived as a hobby or an unproductive waste of time (Mackereth and Anderson 2000). In the last few years, authors, editors, and researchers in game-based learning (GBL) have adopted the term serious game to pinpoint the serious nature that a game can have in the development of learning, health, or other “serious” objectives considered by adults as profitable. Serious games permit to develop playful learning situations related to disciplinary areas and to twenty-first-century skills such as collaboration, problem-solving, and creativity (Connolly et al. 2012). Among serious games, those having learning objectives could be named under the name of educational serious games (ESG). In secondary education, ESG are developed within the different disciplines of the curriculum such as mathematics (Ke 2013), science and technology (Barma and Daniel 2017; Hodges et al. 2018), history, and language learning (Patino et al. 2016). History serious games such *Frequency 1550* (Huizenga et al. 2009) possess a game universe allowing to engage the learners in Amsterdam at 1550. Other popular digital games in secondary schools such *Classcraft* are based on popular entertainment games (Sanchez et al. 2017).

Digital Game-Based Learning in Secondary Education

Within the educational games, this section introduces digital game-based learning (DGBL),

serious games, and educational gamification in secondary schools including four types of activities:

1. *Educational purpose or “modding” of entertainment games.* The pedagogical use of digital games that were not specifically conceived for learning or for the pedagogical use of games without educational intentions, for example, the use of *Minecraft* to work on social sciences (citizenship) or mathematical concepts (Hill 2015; Isiksal and Askar 2005).
2. *Educational serious games.* The pedagogical use of educational serious games (ESG) conceived with a “serious” educational goal, such the mobile city game called *Frequency 1550*, developed to help secondary education learners to develop historical knowledge of medieval Amsterdam (Huizenga et al. 2009). Within the last years, the use of augmented reality (AR) and virtual reality (VR) in educational serious games in the field of science and technology has allowed to approach abstract concepts in a dynamic way through games specifically developed for learning concepts such as electromagnetism (Barma and Daniel 2017) or chemistry (Hodges et al. 2018) in secondary education. Some ESG are based on simulations, defined as “analogies of a real-world situation” (Prensky 2001, p. 128), in which the learner has the possibility to play with a model or microworld in order to better understand a system.
3. *Educational gamification.* Educational gamification engages game mechanics in an educational context, such in the field of science education (Su and Cheng 2015). In some contexts, “framing an activity as a game” has induced the learner to a similar engagement and psychological relation to the activity as using game mechanics (Lieberoth 2015). In terms of learning performance, gamification has showed mixed results (Seaborn and Fels 2015), specially when the gamification is based in game elements such as scores and leaderboards (Toda et al. 2017).
4. *Game design and creation.* In this case, the interest resides in the interdisciplinary design

procedure of a game. Creating a game is considered as a knowledge modeling activity, which can engage in secondary level learners in same-age or intergenerational game design activities (Cucinelli et al. 2018).

Conclusion

Learning through gaming is not limited to children, and secondary education has been integrating educational serious games (EGS), repurposed entertainment games, gamification systems, and game design and creation activities within the last years. While results point to certain benefits in terms of performance in certain tasks, the most important aspect is the learners' engagement and the playful intention which is shared within these different initiatives. Research studies in the next years should continue to study the impact and effects of EGS, repurposed entertainment games, gamification systems, and game design and creation activities taking into account not only the specific game components such the Learning Mechanics and Game Mechanics (Arnab et al. 2015; Proulx et al. 2016) but also the state-of-the-art frameworks and methodologies within the different disciplines concerned by DGBL studies: from the learning sciences and psychology (Boyle et al. 2016), computer sciences and human-computer interaction (Romero et al. 2012), narrative and storytelling (Boyle et al. 2014), and other disciplinary and cross-disciplinary studies. The development of empirical studies including learning analytics adapted to DGBL leads to the emergence of the playing analytics (Sanchez and Mandran 2017), which can contribute to better understand the learning process within the game-based learning activities developed in digital environments. Through the playing analytics, data could be used to develop adaptive systems embracing the potential of machine learning for education in the next generation of educational games for secondary education but also in other educational levels.

Cross-References

- Educational Assessment, Educational Data Mining, and Learning Analytics
- Educational Resources, Hypermedia
- Game-Based Learning
- Games, Simulations, Immersive Environments, and Emerging Technologies
- Gamification

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Computing and Informatics

- Educational Support on Computing and Informatics for Disadvantaged Groups, An Empowerment Perspective

Computing Curricular Report CE2016, A Summary

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Synonyms

Computer education; Computer engineering;
Computing education; Engineering education

Overview

The report titled, *Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering (CE2016)* (Impagliazzo et al. 2016), better known as CE2016, was an endeavor conducted by the Association for Computing

Machinery (ACM) and the IEEE Computer Society. This article is largely based on a culminating paper for the project (Nelson et al. 2017) that reflects an integration of material from earlier workshops and presentations; it also summarizes the content that led to the ACM publication of the CE2016 report in December of 2016. CE2016 is part of a series of reports covering curricula for a variety of computing fields. This article discusses significant aspects of CE2016 and the ways institutions might use the report to update or create computer engineering programs.

The computer engineering field has witnessed rapid advances over the past decade and the field expects to continue to advance even more rapidly. To help in the design of forward-looking curricula to prepare graduates of computer engineering programs for practice, the CE2016 report draws upon an earlier report titled, *Computer Engineering 2004: Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering*, also known as CE2004 (Soldan et al. 2004). This 2004 report also draws upon recent efforts in computing curricula developed by the ACM, IEEE, and the Association for Information Systems (AIS). These efforts resulted in published curricula recommendations in computer science (CS2013), information systems (IS2010), information technology (IT2017), and software engineering (SE2014). These reports are available online at the ACM website (ACM curricular website).

CE2004 set out the technical, communication, and professional competencies important at the time. It discussed the state of the field, and the role of the laboratory, engineering tools, teamwork, and lifelong learning in a computer engineer's education. Many computer engineering programs today reflect the content of this work. To keep up with rapid advances in computer engineering, the societies convened a review taskforce in 2011 to consider whether and how to update CE2004. That taskforce surveyed society members interested in computer engineering and received hundreds of responses. This input identified some new and emerging areas that the community believed should be part of a modern computer engineering graduate's knowledge. These include information security, parallel

processes and algorithms, concurrent hardware and software design, mobile embedded systems, and power-aware software engineering. Guided by this initial input, a steering committee of 11 members incorporated this information into draft revisions of the guidelines, which committee members presented, debated, and refined at many presentations and workshops worldwide. A key contribution of CE2016 is to ensure that the intellectual framework for the discipline remains current with evolving professional practice.

The purpose of the CE2016 report is to provide guidance to programs and present accumulated knowledge for their consideration as they seek to improve continually. The report seeks to help new programs as they invent or re-invent themselves and to supplement the vision of educational institutions, industry, and various accrediting bodies in supporting innovation and quality in academic programs. University faculty can use the CE2016 guidelines to design new programs or to see how their programs align with the expert consensus view of the field and then consider whether updates would better serve their constituents. Employers can use the report to gain insight at the abilities newly graduated computer engineers might possess. Potential students might use them to see how the field aligns with their interests.

The Discipline of Computer Engineering

To provide a context for curricular design, CE2016 defines computer engineering as a discipline, discusses how the field has evolved, and discusses characteristics of computer engineering graduates. CE2016 distinguishes computer engineering from computer science, electrical engineering, software engineering, and other disciplines. As an academic field, computer engineering encompasses the broad areas of electrical or electronics engineering and computer science. CE2016 defines this discipline as follows.

Computer engineering is a discipline that embodies the science and technology of design, construction, implementation, and maintenance of software and hardware components of modern computing systems and computer-controlled equipment.

This unique combination prepares students for careers that deal with computer systems from their design through their implementation. Computing systems are components of a wide range of products such as fuel injection systems in vehicles, medical devices such as X-ray machines, communication devices such as smart phones, and household devices such as alarm systems and washing machines. Designing computing systems and computing components for products, developing and testing their prototypes, and implementing them to market are examples of what computer engineers typically do.

The CE2016 report describes the expected background, knowledge, and skills employers expect to see from graduates of computer engineering programs. These include the ability to design computer systems, the realization of the importance of practicing as professionals, and having the breadth and depth of knowledge expected of a practicing engineer. It also discusses ways in which programs in computer engineering may have to stand up to the scrutiny of validation and accreditation by government or private agencies.

CE Body of Knowledge

The foundation for CE2016 is a fundamental body of knowledge from which an institution could develop or modify a curriculum to fit its needs. This body of knowledge (BoK) contains broad knowledge areas that are applicable to all computer engineering programs worldwide. Changes within this rapidly changing field since the previous report and projections for the next decade prompted significant revisions to the BoK for CE2016.

The BoK has a three-level hierarchical structure. The highest level is the *knowledge area* (KA), which represents a disciplinary subfield of computer engineering. The 12 knowledge areas of CE2016, listed in Table 1, each contain an *area scope* that describes its context. Each area then contains smaller divisions called *knowledge units* (KUs), which represent individual themes within an area. To capture the sense of what students

Computing Curricular Report CE2016, A Summary, Table 1 CE2016 knowledge areas

Tag	Knowledge area	Core hours
CE-CAE	Circuits and electronics	50
CE-CAL	Computing algorithms	30
CE-CAO	Computer architecture and organization	60
CE-DIG	Digital design	50
CE-ESY	Embedded systems	40
CE-NWK	Computer networks	20
CE-PPP	Preparation for professional practice	20
CE-SEC	Information security	20
CE-SGP	Signal processing	30
CE-SPE	Systems and project engineering	35
CE-SRM	Systems resource management	20
CE-SWD	Software design	45
	Total	420

should learn in connection with each knowledge unit, CE2016 uses *learning outcomes* to describe each knowledge unit. The emphasis on *learning* is important. Taxonomies of verbs such as “define” or “evaluate” are useful to describe the expected depth of learning. Levels of learning range from basic abilities, such as reciting definitions, to advanced abilities, such as engaging in synthesis and evaluation. The verbs used to describe learning outcomes in KUs reflect those mentioned in Bloom’s taxonomy (Bloom 1956). Hence, *learning outcomes* provide a mechanism for describing not just knowledge and relevant practical skills but also personal and transferable skills. They describe what we expect a student to know or be able to do by the time of graduation. We can infer the minimal desired depth of coverage associated with each knowledge unit from the language used to express the learning outcomes.

One of the goals in creating CE2016 was to keep the required component of the BoK as small as possible. This allows computer engineering programs to be as flexible as possible since program goals or objectives vary widely from program to program. To implement this principle, the report distinguishes among the KUs by identifying those that are *core* or essential units to the

curriculum compared to those that are *supplementary*. Core components comprise knowledge and skills for which there is broad consensus that anyone obtaining a 4-year degree in the field should acquire. Supplementary components comprise knowledge and skills that reflect expectations for advanced work according to the needs of a program. Table 2 shows the knowledge area for embedded systems with its related knowledge units. KUs CE-ESY-1 to CE-ESY-12 are core units; CE-ESY-13 is supplementary.

To give readers a sense of the time required to cover a knowledge unit, CE2016 expresses time in hours, specifically in *core hours*. Core hours are suggested time of initial exposure to new material and do not assume any delivery method (traditional lecture, video lecture supporting a flipped classroom, directed study, seminar, etc.). As shown in Table 1, the core hours of the BoK total 420, which is the equivalent of one academic year, leaving ample time for additional coverage of core and elective KUs, math and science, and

general studies. Thus, a program may tailor the curriculum to meet its own unique objectives.

In working with the CE2016 guidelines, it is important to realize that the core components refer to the knowledge and skills all students in all computer engineering degree programs *should* attain. Additionally, the knowledge areas are *not* courses, and the core components do *not* constitute a complete curriculum; each program may choose to cover the core knowledge units in a variety of ways. Supporting mathematics, science and general studies are necessary to produce a competent computer engineer. Furthermore, it is not the case that a program should achieve core knowledge units only within a set of introductory courses early in the 4-year curriculum: while some core knowledge units are introductory, a program can address some core KUs only after students have developed significant background in their studies.

Beyond the computing knowledge areas, CE2016 recommends that a robust computer engineering program have at least four areas of capability that require at least 120 hours in mathematics to produce a competent computer engineering professional for the 2020s, although programs typically include much more mathematics to achieve their goals. The four areas, for which core knowledge units appear in the report, include analysis of continuous functions (calculus), discrete structures, linear algebra, and probability and statistics. These emphasize what the steering committee considers essential to computer engineering.

Computing Curricular Report CE2016, A Summary, Table 2 Embedded systems KA with its related KUs

CE-ESY	Embedded systems [40 core hours]
CE-ESY-1	History and overview [1]
CE-ESY-2	Relevant tools, standards, and/or engineering constraints [2]
CE-ESY-3	Characteristics of embedded systems [2]
CE-ESY-4	Basic software techniques for embedded applications [3]
CE-ESY-5	Parallel input and output [3]
CE-ESY-6	Asynchronous and synchronous serial communication [6]
CE-ESY-7	Periodic interrupts, waveform generation, time measurement [3]
CE-ESY-8	Data acquisition, control, sensors, actuators [4]
CE-ESY-9	Implementation strategies for complex embedded systems [7]
CE-ESY-10	Techniques for low-power operation [3]
CE-ESY-11	Mobile and networked embedded systems [3]
CE-ESY-12	Advanced input/output issues [3]
CE-ESY-13	Computing platforms for embedded systems

Numbers in brackets indicate approximate core hours for each essential KU

CE Curricula

By its very nature, a computer engineering program should reflect an engineering ethos that permeates all years of the curriculum in a consistent manner. Such an approach has the effect of introducing students to engineering (particularly computer engineering), teaching them to think and function as engineers, and setting expectations for the future. Preparation for practice is essential because most graduates from 4-year programs directly begin professional practice in much of

the world. Therefore, CE2016 goes beyond defining the body of knowledge to discuss integration into the curriculum of engineering design, laboratory experience, problem-solving, and critical thinking skills, as well as providing the background to adapt to new and emerging technologies in an agile manner. In addition, personal (soft) skills, oral and written communication skills, teamwork, lifelong learning skills, and professionalism are fundamental to preparation for professional practice of computer engineering.

Design must pervade the entire computer engineering curriculum, with students encountering different approaches to design so that they become familiar with the strengths and weaknesses of these approaches. The concept of a culminating design project is a widely valued important experience occurring toward the end of a curriculum. Students consider a significant problem associated with a discipline and, in solving the problem, they demonstrate their ability to apply methodically engineering principles to generate a solution. For computer engineering, the solution typically involves the design and implementation of a system or subsystem containing both hardware and software components and considering a variety of interactions and tradeoffs.

Laboratory experiences are likewise an essential part of the curriculum. It is important that computer engineering students have many opportunities to observe, explore, and manipulate characteristics and behaviors of actual devices, systems, and processes. This includes designing, implementing, testing, and documenting hardware and software, designing experiments to acquire data, analyzing and interpreting that data, and using that data to correct or improve the design and to verify it meets specifications. To support such experiences, CE2016 includes an appendix that describes possible laboratory configurations useful for developing modern student laboratory experiences for computer engineering programs.

Since computer engineering is a profession, CE2016 also addresses incorporation of professional issues throughout the curriculum. It is important that the curriculum include a wide range of professional practice issues, including

consideration of the social context in which graduates implement engineering designs, legal and ethical issues and codes, and professionalism in the workplace.

Curricula Implementation

To illustrate how to apply the guidelines of CE2016 within different institutional contexts, the report provides several sample curricula implementations for computer engineering programs as appendices. To provide a framework for a curriculum that illustrates the ideas presented in the report, the first three examples assume that each year consists of two semesters with a student studying four to five modules (courses) per semester, and students should experience at least two computer engineering modules in the 1st year of study, at least four modules in the 2nd year of study, and at least five modules in each of the 3rd and 4th years of study. Many institutions in the United States use the above pattern; the same is true in many other parts of the world. The fourth example of a curriculum implementation represents a typical 4-year program in China. The remaining example shows possible curricula reflecting those compatible with the Bologna Declaration in Europe.

All sample curricula in the appendix of the report use a common format with five components. They include (a) a set of educational objectives for the program of study and an explanation of any assumed institutional, college, department, or resource constraints; (b) a summary of degree requirements, in tabular form, to indicate the curricular content in its entirety; (c) a sample schedule that a typical student might follow; (d) a map showing coverage of the computer engineering body of knowledge by courses in the curriculum; and (e) a set of course descriptions for those courses in the computing component of the curriculum.

Appendix A of this article presents a sample 4-year computer engineering curriculum model that an electrical and computer engineering (ECE) department might administer. Appendices in the CE2016 report also demonstrate how the core knowledge units of the CE2016 BoK map to the 12 BoK

Appendix A

Course	Description	Credit	Course	Description	Credit
Semester 1			Semester 2		
MTH 101	Calculus I	3	MTH 102	Calculus II	3
CHM 101	Chemistry I & Lab	4	PHY 101	Physics I	3
CSC _A 101	Introduction to Computer Programming	4	CSC _A 102	Intermediate Computer Programming	4
	English Composition I	3	ECE _A 101	Introduction to ECE	2
	Humanities Elective	3		English Composition II	3
	<i>Total credit hours</i>	17		<i>Total credit hours</i>	15
Semester 3			Semester 4		
MTH 201	Calculus III	3	MTH 203	Differential Equations	3
PHY 201	Physics II	3	MTH _A 204	Discrete Structures	3
ECE _A 201	Digital Devices & Lab	4	ECE _A 202	Microprocessors & Lab	4
CSC _A 201	Data Structures	3	ECE _A 203	Circuits/Electronics I	3
MTH 202	Linear Algebra	3	MTH 205	Probability & Statistics	3
	<i>Total credit hours</i>	16		<i>Total credit hours</i>	16
Semester 5			Semester 6		
CSC _A 301	Algorithms	3	CSC _A 302	Client/Server Programming	3
ECE _A 301	Circuits/Electronics II & Lab	4	ECE _A 303	Signals & Systems	3
ECE _A 302	Digital System Design & Lab	3	ECE _A 304	Data Communication	3
	Humanities Elective	3	ECE _A 305	Computer Architecture	3
				Social Science Elective	3
	<i>Total credit hours</i>	13		<i>Total credit hours</i>	15
Semester 7			Semester 8		
ECE _A 401	CE Design I	2	ECE _A 402	CE Design II	2
ECE _A 403	Embedded Systems & Lab	3	ECE _A 404	Computer Security	3
ENG 401	Writing for Engineers	3	ECE _A 405	Operating Systems	3
	CE Technical Elective	3		CE Technical Elective	3
	Fine Arts Elective	3		Social Science Elective	3
		14			14

knowledge areas to required course in the curriculum. The report also provides a short description of each course used with the sample curriculum.

Conclusion

The CE2016 guidelines support the design of computer engineering curricula that will prepare graduates to function at entry-level positions in industry for continued career growth or to enter graduate programs for advanced study. The recommendations reflect input from industrial and educational institutions. This report is the result of a cooperative global effort of the professionals involved. Its intent is to provide interested parties

and educational institutions worldwide a flexible way to implement a strong program in computer engineering. The CE2016 steering committee trusts that it has achieved that goal.

Cross-References

- [Birth of Information Systems Curricula in Victoria in Colleges of Advanced Education and Universities](#)
- [Computing Curricular Report IT2017, A Summary](#)
- [Pedagogical Possibilities for the History of Computing](#)
- [Why Teach History of Computing?](#)

Appendix A. Four-Year Model for Sample Curriculum A (Administered by an ECE Department)

Notation:

ECE_A201: 2nd year course offered in the ECE department

CSC_A101: 1st-year course offered in the computer science department

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Computing Curricular Report IT2017, A Summary

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Introduction

Over the years, the Association for Computing Machinery (ACM) has directed many efforts to create a series of curricular documents that are ongoing even today. In 2008, ACM and the IEEE Computer Society (IEEE-CS) published the first curricular report for information technology (IT), called IT2008 (Lunt et al. 2008). Since that time, many new technologies emerged and

flourished. In 2012–2013, ACM formed an exploratory committee to decide whether IT2008 required updating. After an affirmative response, ACM formed a task group charged with developing an update of IT2008 that was appropriately forward looking to prepare graduates for the mid-2020s. The report is the 2017 document titled, “Information Technology Curricula 2017: Guidelines for Baccalaureate Degree Programs in Information Technology,” known also as IT2017 report (Sabin et al. 2017a). This chapter provides a summary of the IT2017 report and the IT curricular framework. Developing such guidelines for high quality, rigorous IT degree programs benefits from a comprehensive approach that engages international perspectives and reflects needs and expectations from industry and IT professional societies (Sabin et al. 2015a, 2016a). The IT2017 report is the second edition of the ACM/IEEE-CS Curriculum Guidelines for Baccalaureate Programs in Information Technology; it includes technology and educational advances that occurred since 2008 (Sabin et al. 2015b).

IT2017 Task Group

The IT2017 task group is the committee that developed these guidelines. Its membership consists of 12 professionals, five of whom form the task group’s executive committee. These 12 professionals represent academia (nine) and industry (three). The task group membership encompasses three continents (Asia, Europe, and North America) and five countries (Canada, China, the Netherlands, Saudi Arabia, and the United States). The group members represent many international societies, including ACM, IEEE-CS, two ACM special interest groups (IT Education and Computer-Human Interaction), and other organizations.

The IT2017 task group has worked diligently to make revisions and produce an appropriately forward-looking document that is globally relevant and balances perspectives from educators, practitioners, and IT professionals. The IT2017 task group holds the view that IT programs should prepare students with knowledge and skills in learning contexts that emphasize development of competencies: what students do and how they

demonstrate performance with what they know. The main goal of the task group is to produce a curricular framework and guidelines for world-wide baccalaureate IT degree programs that prepare graduates professionally for current and new technologies for the next decade. To accomplish this goal, the task group has incorporated the results of previous curricular reports as a backdrop for its activities. These include reports on computer engineering, computer science, information systems, and software engineering. In addition, the group decided to conduct many faculty and industry surveys to ascertain multinational indicators, predictors, and sources surrounding information technology as an academic discipline and industry sector.

Vision and Mission

The IT2017 task group has adopted both a vision and a mission for the project. Its vision is “The IT2017 report will become a sought-after and durable set of guidelines for use by educational institutions around the world to help them develop IT curricula for the next ten years!” Knowledge alone is not sufficient to be productive in the changing information technology world. IT competencies require skills and dispositions that complement knowledge to achieve professional expectations of a modern workplace. Therefore, the mission of the IT2017 project is “To produce a globally accepted document of information technology competencies appropriate for baccalaureate degree programs that meets the growing demands of the changing technological world and that is useful for both industry and academia.”

Public Comment

The report contains feedback that the task group received from public comment and review solicited for report versions in January of 2015, August of 2016, and May of 2017. Some task group members participated in two international working groups (Sabin et al. 2015b, 2016a) to lead extensive data gathering and analysis efforts

and to garner input from academia and industry through surveys conducted in 2015 (almost 700 responses, 597 computing faculty and 91 industry respondents) and in 2016 (over 350 responses from Latin America, 182 faculty and 177 employers). Report development dissemination included a variety of venues to engage educational and professional communities worldwide: curriculum design workshop and panel at IEEE EDUCON in Tallinn, Estonia in 2015 (Impagliazzo 2015) and Abu Dhabi in 2016 (Impagliazzo et al. 2016a), and a panel in the first National Computing Colleges Conference in Saudi Arabia in 2016. Other panel sessions on the report status updates occurred at SIGITE conferences in Chicago in 2015, Boston in 2016 (Sabin et al. 2016b), and Rochester 2017 (Sabin et al. 2017b), at the Western Canadian Conference on Computing Education (WCCE’16) in British Columbia, Canada (Byers et al. 2016), and at ITiCSE’16 in Arequipa, Peru (Impagliazzo et al. 2016b).

Definition of the Information Technology Academic Discipline

Worldwide, the term “information technology” generally refers to all aspects of computing and its integration into all aspects of today’s society and digital platform economy. Organizations of every kind are dependent on information technology and computing systems that must work properly and efficiently, be secure, and scale with organizational objectives and customer needs. IT professionals select computing products and services, integrate them to enhance supported environments, and develop, adapt, and manage computing technologies to meet the organization’s goals and business objectives. The IT innovations are the object of study of the information technology discipline. These innovations frame the questions IT professionals and researchers pose and inform the methods and practices by which IT complex problems are solved and new discoveries are made. IT2017 report proposes the following definition of the information technology discipline:

Information Technology is the study of systemic approaches to select, develop, apply, integrate, and administer secure computing technologies to enable users to accomplish their personal, organizational, and societal goals.

IT2017 Curricular Framework

The IT2017 report suggests a learner-centered framework for programs that prepare successful IT graduates for professional careers or further academic study. Inspired by the IT competency model for an associate degree curriculum (Hawthorne et al. 2014) and receptive to industry demands for competent and competitive IT workforce, the IT2017 report has adopted a full competency-based approach to learning IT. The approach is somewhat unique among the ACM/IEEE curricular reports. The report articulates competencies grounded in content of essential and supplemental IT domains. It enables faculty members to implement IT programs that articulate convincingly what student should be able to achieve by the time of graduation.

The IT2008 report’s depiction of the IT discipline’s key curricular components represented five pillars (programming, networking, human-computer interaction, databases, and web systems) built on a foundation of IT fundamentals and overarched by information assurance and security as well as professionalism. For the current situation, the IT2017 framework depiction is an interwoven tapestry of interrelated studies and activities. Another innovative change is the elimination of hours as a measure of domain coverage. A competent graduate from an IT degree program should experience the equivalent of at least 1.5 years of information technology studies. The report provides guidance so IT graduates can perform competitively in the marketplace.

It is possible to consider that a report of this type is much too complex with framework domains and associated competencies. In today’s computing educational environments, it is simply not possible to list only a set of courses with their lists of topics. IT programs vary among institutions. Furthermore, the technological field changes rapidly and what seems important today

may just be a passing fancy. Thus, it is important to prepare students for this undetermined future by establishing foundational competencies coupled with the flexibility to adapt to new situations that await them after graduation.

Structure of the IT2017 Curricular Framework

One of the goals in this IT2017 report is to keep the implementation requirements of the IT curricular framework as few as possible to allow flexibility for programs in information technology. To implement this principle, a distinction among the IT domains occurs by identifying those that are essential to an IT curriculum compared to those that are supplemental. Essential domains encompass competencies that anyone obtaining an IT degree must acquire. Supplemental domains encompass competencies in domains where students do more specialized work according to the goals of a program. Supplemental domains provide IT programs more directed choices, flexibility, and the opportunity to include new domains that could emerge in the future. All degree programs should require students to achieve competencies in some subset of the supplemental domains. Table 1 shows the IT domains as presented in the report together with their essential or supplemental classifications and 19 distinct colors associated with each domain. Note that some domains cross both essential and supplemental classifications. The table also shows the percent associated with each domain relative to the entire IT curriculum in a baccalaureate IT degree program.

The IT2017 task group has recommended that the breakdown of an IT curriculum in a baccalaureate degree program consists of approximately 40% from the essential IT domains, approximately 20% from the supplemental IT domains, and the remaining 40% representing IT electives. A summary of the IT curricular framework appears in two tables in the report; one table for the essential IT domains and the other for the supplemental IT domains. The tables show the IT domains, their subdomains, and the level of learning engagement for each subdomain



Computing Curricular Report IT2017, A Summary, Table 1 Competency domains of the IT curricular framework

IT Domains	Essential Percent	Supplemental Percent
Essential Only (5)		
Information Management (IMA)	6%	0
Integrated Systems Technology (IST)	3%	0
Platform Technologies (PFT)	1%	0
System Paradigms (SPA)	6%	0
User Experience Design (UXD)	3%	0
<i>Subtotal:</i>	19%	0
Essential + Supplemental (5+5)		
Cybersecurity Principles (CSP) / Cybersecurity Emerging Challenges (CEC)	6%	4%
Global Professional Practice (GPP) / Social Responsibility (SRE)	3%	2%
Networking (NET) / Applied Networks (ANE)	5%	4%
Software Fundamentals (SWF) / Software Development and Management (SDM)	4%	2%
Web and Mobile Systems (WMS) / Mobile Applications (MAP)	3%	3%
<i>Subtotal:</i>	21%	
Supplemental Only (4)		
Cloud Computing (CCO)	0	4%
Data Scalability and Analytics (DSA)	0	4%
Internet of Things (IOT)	0	4%
Virtual Systems and Services (VSS)	0	4%
<i>Subtotal:</i>	0	
IT2017 TOTAL Essential Domain Competencies:	40%	

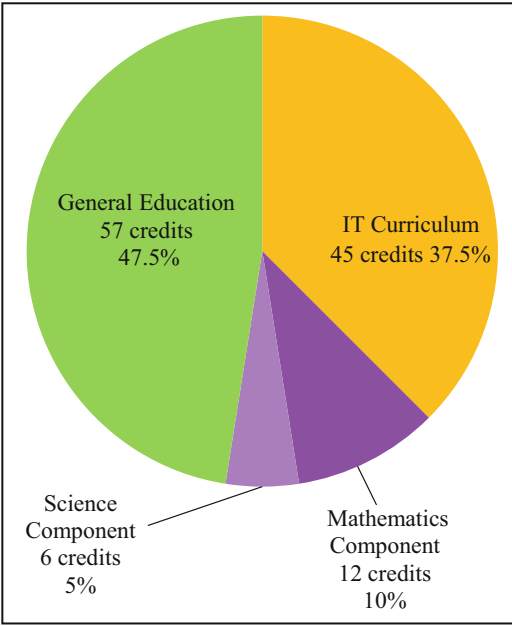
expressed by level indicator shown in brackets. Tags differentiate the different domains and subdomains.

Assume an IT program consists of 120 credits (semester hours) over 4 years. Then at least 1.5 years of study consists of at least 45 credits or 37.5% of the program. The mathematics curriculum should be at least 12 credits (10%) and the science curriculum should be at least 6 credits (5%) as recommended by the task group. Figure 1 illustrates the curriculum requirements for an baccalaureate IT program. Note that the other curricula in the program (47.5%) could consist of any combination of IT and non-IT subjects reflective of the mission and needs of the program.

IT Domain Clusters

A competency-based IT curricular framework considers the long-term goal of learning to achieve genuine competence through ongoing transfer that spans what students learn through college and graduates develop in their profession. By using a competency-based approach, IT faculty members who implement, evaluate, or update their IT programs need to rethink the IT domains through the lens of performance goals and how students demonstrate what they can do with what they have learned.

To guide departments and faculty members through a competency-based curriculum



Computing Curricular Report IT2017, A Summary, Fig. 1 Example of a curriculum for an IT program of 120 credits, with IT, mathematics, and science curricular requirements

development process, the report uses IT domain clusters to describe the IT curricular framework’s domains. The purpose of an IT domain cluster is to connect directly the scope of the domain with competencies that students achieve within a domain with a more refined characterization of domain content through subdomain information. Table 2 offers an example of IT domain cluster for the Software Development and Management essential domain.

IT Competencies

Generally, the term competence refers to the performance standards associated with a profession or membership to a licensing organization. Assessing some level of performance in the workplace is frequently used as a competence measure; that is, measuring aspects of the job at which a person is competent.

There is general agreement in education that success in college and career readiness requires

Computing Curricular Report IT2017, A Summary, Table 2 Example of IT domain cluster

Essential competency domain: software development and management	
Scope	
1. Software process models and software project management	
2. Software development phases: requirements and analysis, design and construction, testing, deployment, operations, and maintenance	
3. Modern software development and management platforms, tools, and services	
Competencies	
A. Use tools and services to develop computing systems that consider platform constraints, supports version control, tracks requirements and bugs, and automates building (<i>Development</i>)	
B. Use project management tools and metrics to plan, monitor, track progress, and handle risks that affect decisions in a computing systems development process involving a diverse team of talents and professional experiences (<i>Management</i>)	
Subdomains	
Process models and activities	Management
Platform-based development	Deployment, operations, and maintenance
Tools and services	

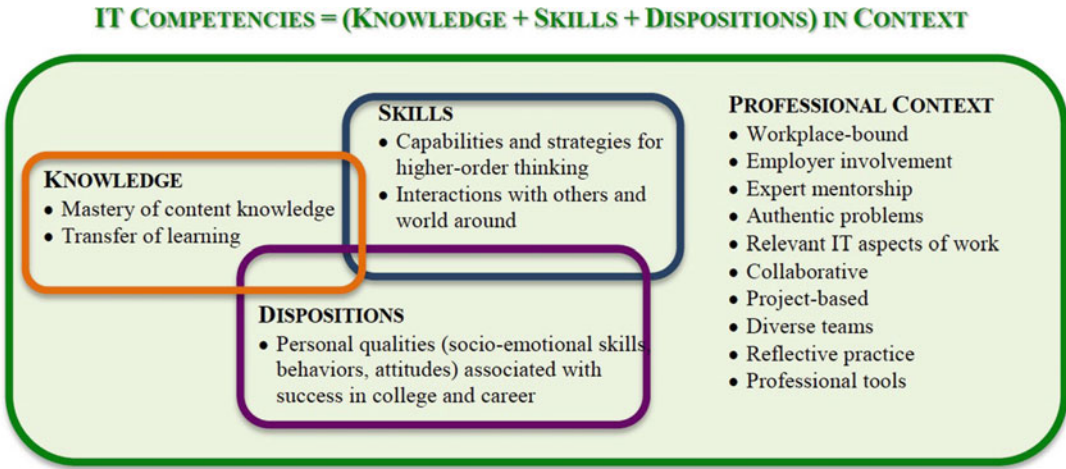
that students develop a range of qualities, typically organized along three dimensions: knowledge, skills, and dispositions. The IT2017 report has adopted a working definition of *competency* that connects these dimensions, namely:

Competency = Knowledge + Skills

+ Dispositions

The working definition of competency in the IT2017 report avoids perpetuating the practice of preponderantly using the knowledge lens and centering curriculum guidelines primarily on a body of knowledge of IT. The task group note that recent ACM computing curricula reports for IT associates degree programs and graduate programs in information systems have also adopted a competency model approach (Hawthorne et al. 2014).

The basis for constructing a curriculum that is competency-driven is to align learning outcomes, activities, and assessments. On a practical,



Computing Curricular Report IT2017, A Summary, Fig. 2 IT competency model

operational level, the IT2017 task group conceptualized competencies as higher-level learning outcomes linked to performance tasks and descriptive of the professional context of those tasks. The task group follows Van der Klink and Boon advice that the “fuzziness” of competencies “disappears in the clarity of learning outcomes.” A sensible method to articulate competencies is to select learning outcomes along with evaluation indicators suggestive of a professional context. A performance perspective on learning is not possible without performance-based assessments. The design of performance assessments considers authentic situations and aspects of work that professionals encounter and through which they demonstrate expertise. Thus, a promising practice to implement a competency-based curriculum is to identify and link the curriculum to professional contexts. The task group’s operational definition of IT competencies connects knowledge, skills, and dispositions in a professional context as shown in Figure 2.

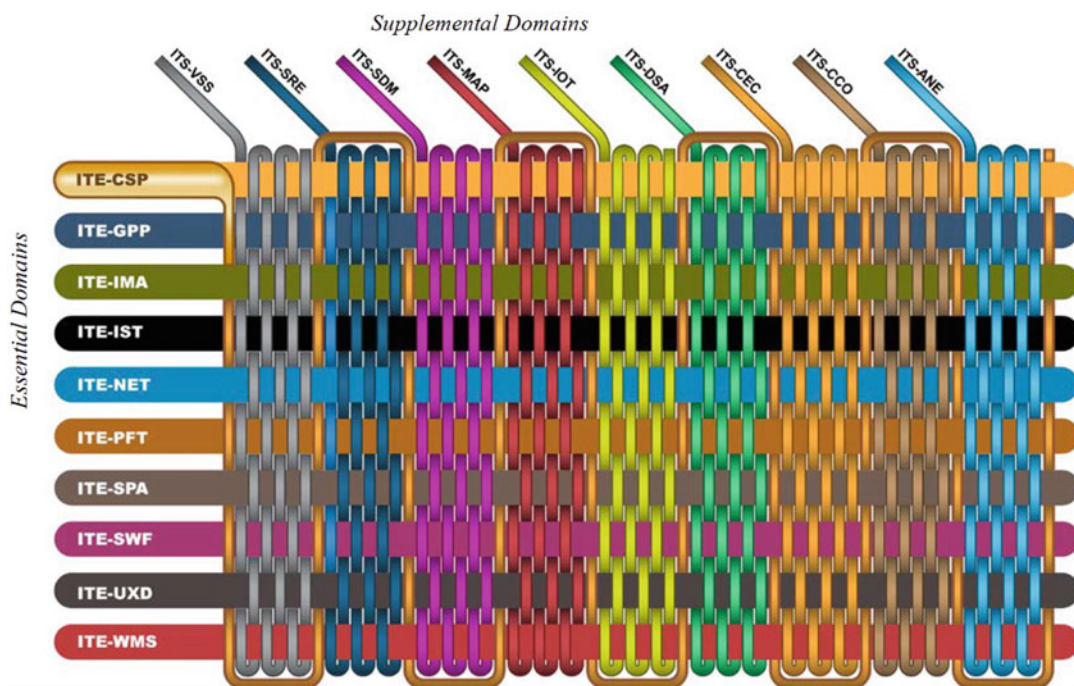
Contemporary Illustration of IT

Recall that the essential domains form the core of an IT curriculum. The supplemental domains provide

texture with enhancements and embellishments to reflect the local needs of a program’s mission and constituents. That is, a modern image should depict the essential and the supplemental meanings of a curriculum carefully woven together into a tapestry of relevance and utility for the IT field.

Figure 3 illustrates a tapestry as a modern version of information technology. For this illustration, the weft threads (vertical) of the tapestry go through the warp threads (horizontal). In this case, the ten warps represent the ten essential domains of the IT curricular framework; the nine wefts represent the nine supplemental domains of the framework. Note that one warp thread (ITE-CSP) permeates both warp and weft roles in the image, which emphasizes that cybersecurity is a contemporary “thread” woven throughout the tapestry – and hence, the field of information technology. This woven warp thread may change name over time as IT evolves. The resulting image provides a pictorial illustration showing the way IT weaves the breadth of computing.

New technologies keep emerging thereby amplifying the integration of IT competencies. Figure 3 attempts to capture the spirit of future IT innovations by allowing the warp threads and the weft threads to weave the tapestry of a dynamic and relentlessly evolving IT field.



Computing Curricular Report IT2017, A Summary, Fig. 3 Modern illustration depicting the field of IT. (Courtesy of Richard Fry)

Content of the IT2017 Report

The IT2017 report addresses baccalaureate degree programs in information technology. The main body of the report consists of eight chapters. Chapter 1 introduces the report. Chapter 2 discusses the role of IT among other computing disciplines and proposes a new definition for the information technology discipline. It also describes competencies that students develop through their program of study and should demonstrate upon graduation. Chapter 3 highlights the importance of professionalism in the practice of information technology. Chapter 4 discusses the meaning of competencies and proposes an operational definition for information technology competencies. Chapter 5 discusses an industry perspective toward information technology. It includes current data and graphs related to IT competencies from IT employers' viewpoint.

Chapter 6 presents an overview of the IT curricular framework and describes a basis for curricular recommendations. The vision, mission, goals, underlying principles, perspectives from industry, and professional practice inform this framework. The chapter also articulates various IT competency domains of the curricular framework, the percent of time devoted to an IT curriculum in a degree program, mathematics and science curricular requirements, and various competencies an individual need to become an effective professional in information technology.

Chapter 7 provides a discussion on transforming competencies into a curriculum; it also discusses issues affecting the implementation of an IT curriculum such as the arrangement of a student's program of study, inclusion of courses within the major and those in other areas of the educational experience as well as other implementation considerations. Chapter 8 discusses some

challenges that may arise when creating or continuing IT programs such as curriculum design, computing resources, and faculty issues.

The bulk of the material in the report appears as five appendices. Appendix A presents part of the first chapter in the Enterprise Information Technology Body of Knowledge (EITBOK) report currently under development by the IEEE Computer Society. Appendix B gives examples of IT performances related to various IT domains and their subdomains. These performances may be useful for developing learning outcomes for a given IT course or possible questions to assess student performance. Appendix C illustrates typical sample curricula that might appear at different academic institutions together with related mappings of the framework and course descriptions. Appendix D provides samples of other IT programs (e.g., interdisciplinary, 3-year, 2 + 2, etc.). Appendix E recognizes reviewer contributors.

Conclusion

No single procedure for success exists in producing an information technology curriculum. Although the task group believes that the recommendations and the specific strategic suggestions of the report should prove useful to a wide variety of institutions. Students of information technology should consider taking job-specific courses toward the end of their studies to arrange themselves for the skills that are current and in demand in the marketplace.

Moreover, it is important to evaluate and adjust curricular programs on a regular basis to keep up with the rapid changes in the field. Information technology curricula that already exist today are the product of several years of experimentation and refinement by information technology educators at their own institutions in collaboration with IT professionals and business and industry leaders. Future IT curricula will depend just as much on the creativity and the academia-employer partnerships that follow in the wake of this report to build even stronger information technology programs for undergraduates throughout the world.

Cross-References

- [Computing Curricular Report CE2016, A Summary](#)

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Computing Education

- [Computers in Secondary Schools](#)
- [Computing Curricular Report CE2016, A Summary](#)
- [Computing Education, Practices in](#)
- [Teaching About Computing](#)
- [Why Teach History of Computing?](#)

Computing Education, Outcomes of

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Synonyms

[Computational thinking](#); [Computer science education](#); [Informatics](#); [Information and communication technologies](#); [Problem-solving](#)

Introduction

In this entry, how outcomes of computing education can be conceived and considered is initially

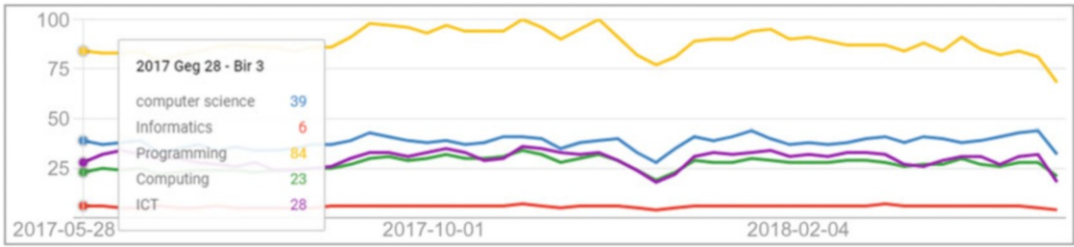
discussed. Later, returning to explore more deeply the current situation across a range of countries, identifying contemporary outcomes of computing education.

The underpinning subject area for computing education, computer science (CS), is quite a young science, which has different names worldwide. In order to demonstrate the variety of terminologies applied to this subject area, the Word Cloud of 71 (Falkner et al. 2014) shows that the words most frequently associated are computer, science, and programming. Similarly, a chart of Google Trends shows that programming and computer science terms were the most popular keywords used in the Google search engine worldwide between May 2017 and May 2018 (see Fig. 1).

In some countries, computer science is called informatics – a distinct scientific discipline, characterized by its own concepts, methods, body of knowledge, and open issues. For example, currently Korea is using the term informatics education; previously the term computer education was used until 2007, being similar to information technology (IT) education, information and communication technologies (ICT) education, and computer science education (CSE) (Choi et al. 2015). Informatics education covers the foundations of computational structures, processes, artifacts, and systems, as well as their software designs, their applications, and their impact on society (CECE 2017).

The meaning of CS has changed through the years, since it is constantly reshaped, due to new thinking approaches and emerging technologies. For example, the widely used concept of ICT has moved within ICT education from uses of ICT as a tool (with the development of digital literacy as a key requirement) toward understanding the underpinning concepts and workings of ICT (Falkner et al. 2014). So, ICT fundamentally concerns effective uses of technology.

Related to shifts in the uses and meanings of terms, it is important to focus also on the movement from using technologies as consumers to working with technologies as developers



Computing Education, Outcomes of, Fig. 1 Google Trends results

or producers (supported by digital technologies). This idea is clearly presented in the Australian Curriculum: “Digital Technologies,” which explains the differences between ICT capabilities and digital technologies (Australian Government Department of Education and Training 2018). However, having abilities in computer science is concerned not only with knowledge about computers and ICT, as computer scientists need to know much more. Thus, the focus on computing in education rather than solely on ICT is desirable (Passey 2017). In this respect, computers and the ongoing development of the internet continue to change opportunities and needs for education. Computers and networking provide opportunities for both learning and teaching enhancements, but these require users to have additional skills such as those connected with the concept of digital literacy (DL), where DL covers fluency with standard software tools and the Internet (CECE 2017). Nowadays, it is commonly agreed that such literacy is fundamental for a digitally enabled world society. The European Commission has promoted a Digital Competence Framework 2.0 as a tool to review and potentially improve citizens’ digital competence (DigComp 2016). Such competence is not only important for everyday use but also for future prospects. By 2020, for example, the ICT sector will need employees that possess and can deploy five essential skills: complex problem-solving; critical thinking; creativity; people management; and coordinating or collaborating with others. These generic skills will be essential, as technological skills for IT specialists need to collaborate with various sectors, not only within their industry

but increasingly with their users. Industry is adapting to these changing needs, so educational institutions must also adapt, as they play an important role in preparing future employees. The curricula need to be attractive (to meet the needs of digital age learners); and computing education needs to develop both technological and generic skills.

Computing education as a school subject covers all the abovementioned strands (informatics, computer science, ICT, and digital literacy). There are three main areas covered: information technology (abilities to deal with digital systems); digital literacy (abilities to use a computer confidently, effectively, and safely, with moral and ethical understanding); and computer science (developing and using algorithms, data structures, programming, systems architecture, design, and problem-solving) (The Royal Society 2017, p. 16).

In terms of outcomes (the result or effect of an action, situation, or event) of computing education, there may be impacts on learners, which might be short or long term. Educators and government are concerned with focus on the long term, as computing education needs to meet the demands of the digital age learner and to develop essential skills for life. The curriculum and global policies, in this respect, should aim to guide educators in order to develop a learner’s computing competencies for life. Such documents and policies should provide for the aims and intentions for computing education that educators translate into teaching and learning practices. However, the evaluation of such aims and intentions can be considered as a research impact assessment in itself (Esposito et al. 2018).

Curriculum and Policies

Computing education can be taught in schools in different ways. Some countries have computing-related courses as mandatory subjects, some as an elective-only subject (in Korea), but even these elective subjects can be at different educational levels (as in Lithuania, Austria, Slovakia). Some countries integrate the subject and use a multi-disciplinary approach (in Finland, France) or integrate it in all subjects and also as an optional separate subject (in Norway); others do not have such a subject or curriculum (Italy currently has no curriculum for primary education) or specific policies or guidelines (in Ireland). Thus, there are some countries where, after finishing compulsory education, learners have had no experience of any computer science-related subject.

The incorporation of CS into compulsory education has two main goals: CS helps students to acquire competencies that are necessary in current society and its strength as an element of equity to reduce inequalities of gender, race, social origin, or economic level, such as to eliminate the stereotypes that make it difficult for women to take an interest in these studies (Cabrera-Delgado 2017). The overall availability of informatics courses (elective and compulsory) in 2017 across European countries is presented in “Informatics Education in Europe” (CECE 2017, p. 14), and CS in terms of provision within the compulsory education sector in 2015 is discussed by Passey (2017).

In a number of countries, the authorities responsible for curriculum development are government ministries (in Austria, Norway, Lithuania). In Austria, the federal authorities (i.e., the Ministry of Education) have an exclusive responsibility over legislation and implementation in the entire field of education. Similarly, MEXT (the Ministry of Education, Culture, Sports, Science and Technology) publishes the government curriculum guidelines which every teacher in Japan should follow. The Lithuanian Ministry of Education and Science (MoE) is responsible for preparing the main policy documents (such as strategies and implementing

planned programs), establishes the qualification requirements for teachers working in educational institutions, and operates the procedure for attestation of principals and teachers. But in the latter case, there are additional institutions that support policy document implementation (such as the Education Development Center (EDC) and National Examination Center (NEC)). Furthermore, the MoE ensures and accounts for the quality, accessibility, and evaluation process of the system. However, ministries are less involved in some other countries. The ICT programs at national level in Spain are coordinated by the Instituto Nacional de Tecnologías Educativas y de Formación del Profesorado (INTEF), which is the ICT for education unit of the Spanish Ministry of Education (MoE). The Spanish MoE establishes a minimum curriculum for compulsory school levels which is shared by all autonomous communities, but the rest of the curriculum is developed by the regional educational authorities based on their preferences and local characteristics (Fernández 2015). In Finland, the Finnish National Agency for Education (EDUFI) operates under the Ministry of Education and Culture, responsible for developing education and training. A few years ago, both the Finnish government and local administration units (municipalities) supported the use of ICT in education, but now the Finnish education system is completely decentralized. Local municipalities are now fully responsible for ICT in schools (Kimmo 2017). Similarly, the Spanish administration is a highly decentralized system, where autonomous communities are fully responsible for the schools in their territory, which includes the promotion of ICT in schools, and they legislate under the general umbrella of national law (Fernández 2015).

By contrast, the key responsibility for the “National Informatics Curriculum” development in Slovakia is mostly assigned to Comenius University. The authors of the national curriculum include the topics of core informatics along with learning of basic ICT skills. Informatics includes computing, ICT (a set of user-oriented skills), and digital literacy (a set of basic skills to use digital

technology effectively, safely, and meaningfully to solve everyday problems and tasks) (Kabátová et al. 2016).

In other countries, state ministries are involved. Australia has eight states and territories, where each is responsible for education and has its own curriculum, although policy comes from both state and federal governments. CS, informatics, or ICT is mandated through the “Digital Technologies Curriculum” (Australian Curriculum 2017), which was mandatory in the Western Australia (DT 2017 Australian Curriculum), Victoria (Victorian Curriculum 2017), and South Australia (Curriculum in South Australian schools 2017) states in 2017 and is now implemented in other states. Similarly, Germany is a federal republic with 16 States, each responsible for their own curriculum. However, while there is no unique German CS curriculum, the German Federal Parliament (Bundestag) passed a law with regard to “Digital Education” on Digital Media Education/Informatics, Internet Policy.

In other countries, responsibilities are shared. The Directorate of Digital Technologies for Education in France is responsible for matters related to ICT, such as teacher training, preparing, giving a framework, and implementing the guidelines for the development of ICT for educational purposes in schools. The “academies,” regional structures of the French Ministry of Education, are in charge of implementing national directives and policies, which also give impetus to the development of ICT (Terrades and Chibani 2018, p. 5).

Curriculum and Primary Education

However, while national ministries and agencies play their part in what should be learned in schools and the aims of that learning (which clearly affect the outcomes of that computing education), schools also play critically important roles. Typically, schools decide which elective courses to offer, and students can choose which subjects to take. But there are some exceptions. For example, in the Korean educational system, a school chooses a few subjects that are taken by all the same grade pupils (Choi et al. 2015).

Nowadays, the trend to incorporate CS into schools from an early age is increasingly seen. Computing education can involve learning in early elementary education, which is intended to increase pupils’ exposure, attitude, and self-efficacy toward computing. Additionally, it is reported that implementing computing in early education makes pupils “happy, engaged and excited to learn” (Kind 2015). Of course, some authors argue that it is important to incorporate this subject based on pupils’ age, related to complexity of skills. It is argued that it is necessary for a child to have reached a sufficient capacity for abstraction (Cabrera-Delgado 2017), particularly at grades 9–12, or algorithmic thinking that is appropriate at grades 3–5 (Shailaja and Sridaran 2015). In this respect, informatics content and form are developed based on age, gender, or future career of pupils in Slovakia (Kabátová et al. 2016).

In primary education, computing-related subjects are mandatory in England (from 5 to 11 years of age), in Poland (1st–6th grades based on a new curriculum initiative), and in Slovakia (3rd–8th grade and optional in grades 1, 2, and 9). Computing is not taught as a separate subject in France and Finland; it is embedded in all subjects, at both primary and secondary levels. In primary schools in Germany, there is no subject for informatics, but there are ongoing initiatives and experimental projects initiated by state governments and by federal foundations, such as the GI-Working Group for CSE standards in primary education for “Competences for Informatics Education in Primary Education” which offers recommendations for development (Competences for Informatics Education in Primary Education 2018) and the GI-Working Group for CSE standards in primary education development. Similarly, in Japan, the existing curriculum does not include informatics education; furthermore, the majority of teachers do not have training in teaching informatics. However, Japan will make programming education compulsory for primary and middle schools and plans to implement it beyond 2020. To this end, a new curriculum is to be fully implemented at elementary schools from 2020, at lower secondary

from 2021, and at upper secondary from 2022. This new curriculum includes problem-solving, communication approaches, programming and simulation, information systems, as well as data processing, statistical processing, and network programming, which are fundamental technologies of artificial intelligence and the “Internet of things” (Kanemune et al. 2017). Italy has no specific national curriculum for CS for primary education; however, the Italian “National Plan for Digital Education” (Piano Nazionale Scuola Digitale – *PNSD*), a policy launched by the Ministry of Education, Universities and Research, covers all school levels and comprises 35 different actions for gradual implementation that address the five key areas of intervention: tools, skills, content, staff training, and supporting measures. The policy does not change school curricula – it proposes some innovations, such as computational thinking or coding covering all school levels. This plan encompasses the most important digital age education strands: lifelong and life-wide learning, in both formal and non-formal contexts that all together form a long-term vision (Italy National Plan for Digital Education 2016, p. 1). In Korea, computing-related subjects are elective in the elementary (5th and 6th grades) school curriculum. Such content can be found in the “life and information” section of the “practical arts” – a combination of home economics and technology and computer-related contents that are included in the technology part (Choi et al. 2015). The 5th grade student can take a subject on the characteristics of digital devices, how to use them, the traits of cyberspace, and information ethics and the 6th grade student on the meaning of information and how to explore it, together with the utilization of software.

The Lithuanian MoE also agrees that CS must be incorporated into schools at an early stage. Thus, the MoE together with the Center for Development of Education initiated the project “Informatics in Primary Education.” The project was prepared by a working group of scientists, teachers, and education experts. The primary school informatics curriculum consists of six main areas: problem-solving, digital content, algorithms and programming, information and

data, virtual communication, and safety and protection (Informatics in Primary Education 2017). Additionally, a new informatics curriculum will be developed for grades 1–10 with a special focus on the most important informatics concepts and skills (Mannila et al. 2014).

Curriculum and Secondary Education

Computing and ICT secondary school curricula vary widely. While ICT and informatics as a subject are mandatory in grade 9 in Austrian secondary schools, teacher training in this field is not mandatory. An informatics curriculum is only defined for Year 9 and as an optional subject in Years 11–13 (Spieler et al. 2017). Computing is mandatory in secondary schools in England (11–14 years of age) and elective at 14–16 years of age and is also elective at colleges (14–18 years of age) (CECE 2017). Similarly, informatics is compulsory at grade 10 in Slovakian secondary schools and optional at grades 11–13 (CECE 2017). Additionally, ICT elements are integrated across subjects (Kabátová 2016), and Slovakia is also implementing a strategy of integration of digital technologies in education through to 2020, based on “Strategic guidelines for further implementation of ICT in the Slovenian education until 2020” developed by the Slovak MoE. By contrast, a digital technologies curriculum is mandated for all levels of compulsory schooling (Years 5–10) in Australia. In most states in Germany, informatics is an elective subject at higher secondary level, more so at grades 10–13. In many states (e.g., Berlin, Bremen), schools offer informatics as an elective subject and at a lower secondary level (5th–10th grades). Only a few states already implement informatics as a compulsory subject in secondary schools; it is compulsory in the States of Bavaria for grades 6–7, in Mecklenburg-Vorpommern for grades 7–10, and in Sachsen for grades 7–8 (CECE 2017). The optional CS-related subject “technology” is available from the 7th to the 10th grade in Spanish schools. In addition, ICT is offered as an optional subject in the 10th grade. In this subject, students’ ICT competence is directly assessed, and also it is

integrated in all subjects in a transversal way (Fernández 2015). Informatics and programming as a part of a compulsory subject “Technology and Home Economics” which includes topics on computer sensing and control (with programming) are taught in Japan at lower secondary level (grades 7–9). Additionally, the compulsory subject “Information” has two elective subcategories at upper secondary grades (10–12), named “Information Study for Participating Community (Society and Information)” and “Information Study by Scientific Approach (Information Science)” (Kanemune et al. 2017). The first is about model attitudes of participation in information society and the second about scientific understanding of information (CS and its surroundings) including basics of programming and elementary algorithms (Kuno et al. 2015; Guerra et al. 2012). Additionally, MEXT promotes ICT in education under the plan to accelerate ICT (developed July 29, 2016) with a focus on utilizing ICT in the curriculum and special needs education, also improving teachers’ ability to use ICT for instructional purposes, developing children’s information literacy, promoting utilization of ICT for school administrative works, and enhancing information ethics education (Overview of MEXT 2016). As a stand-alone course, informatics is taught as an elective subject in lower and upper secondary schools (grades 8–13) in Norway (CECE 2017).

The subject informatics is compulsory in Lithuanian secondary education (grades 5–10). It is taught as a separate subject and also integrated into other subjects. The content focus is on information and technological competences development. In upper secondary schools (grades 11–12), students can select advanced optional modules.

Informatics as an elective subject is taught in Korean middle schools (grades 7–9) that covers the basic concepts and principles of CS and aims to nurture the students’ ability to observe and resolve diverse practical problems using computational thinking and the ethical attainment of information. In the high school curriculum (grades 10–12), additionally to the informatics subject (with more in-depth content), there is the

possibility to select an information science subject that focuses on connectivity with other subjects, problem-solving abilities, and programming (Choi et al. 2015).

An informatics-related subject—programming—has been piloted since 2016 as an elective subject in Norway in lower secondary schools (grades 8–10) and from 2019 as a permanent elective subject. Trials of programming and modelling in upper secondary schools (grades 11–13) have been started as well (Søby 2018). Additionally, more options on specializations in computing and programming, depending on the specific program that students choose to take, are available in upper secondary schools (Mavroudi and Divitini 2017).

Influences on Policy and Planning

Although Ireland has no national computing curriculum, policies, or guidelines, and no new educational reform was introduced in the last years, the government has launched an “Action Plan for Education 2016–2019” that states an objective to realize the potential of digital technologies to enhance teaching, learning, and assessment so that Ireland’s young people become engaged thinkers, active learners, knowledge constructors, and global citizens, to participate fully in society and the economy. Additionally, according to the “Ireland Digital Strategy for School 2015–2020,” the Department of Education and Skills will provide more appropriate support materials and services to principals and teachers on embedding ICT into their practice, as well as examples of good practice on the effective, critical, and ethical use of ICT for teaching, learning, and assessment based on a localized UNESCO ICT Competency Framework for Teachers (Connolly 2017).

While computing-related curriculum development is generally the responsibility of government (ministries of education particularly), some countries are collaborating with global companies and agencies, such as Spain with Google (Computer Science Education in Spain 2016). Google, in collaboration with the Spanish Foundation for

Science and Technology (FECYT) and Everis, have developed a report on CSE (primary and secondary schools) in Spain with the aim of introduction, extension, and improvement of the CS subject in Spanish schools (Computer Science Education in Spain 2016). In a related way, Italy has collaborated with European Schoolnet and the European Commission (Bocconi et al. 2016).

Education policies have been adopted around the world due to international dissemination of values of Western modernity and the legitimization pressures that governments receive as well as concerns for their comparative education (Verger 2014) or even competitive reasons. However, reasons for such reflections differ. In this respect, the central vision of the “Ireland Statement of Strategy” and “Action Plan for Education” is that the Irish education and training system should become the best in Europe over the next decade (Ireland Action Plan for Education 2018). Likewise, Japan MEXT comprehensively promotes science and technology (based on the “Fifth Science and Technology Basic Plan” FY2016-FY2020) with an aim to becoming the world’s most innovative country. Additionally, Spain has adopted the DigComp model proposed by the Institute for Prospective Technological Studies (IPTS) (European Commission) for any European citizen in connection with the Digital Agenda 2020 and has developed the “Common Framework for Teaching Digital Competence” – a standardized proposal which specifies a teacher’s digital competence through descriptors of 21 sub-competencies organized in 3 levels and 5 competency areas (information, communication, content creation, security, and troubleshooting) (Fernández 2015).

In England, there are three strands in the computing curriculum, which were reported on with recommendations in a Royal Society report: computer science (informatics), information technology, and digital literacy (CECE 2017). The national curriculum was developed by the government Department for Education in England, while CAS (Computing at School) prepared guidance for teachers on how computing could be implemented in schools (Kemp

2014; Berry 2013). These organizations form major parts of a national system for curriculum development, implementation, and assessment.

Curriculum Relationship to Longer-Term Outcomes

Recently, a number of initiatives, action plans, and policy drafts have appeared as a consequence of the call for a long-term vision for education in the digital age. The new “eEducation Austria” initiative of the Federal Ministry of Education (BMB) has focused on digital and CS skills, to increase the ICT competencies of all participants in Austrian schools. Additionally, the digital education strategy “School 4.0. – it’s getting digital” of the Austrian Federal Ministry of Education has been announced, with the view to making ICT and informatics mandatory in primary education (3rd and 4th grades), as well as in lower secondary (5th–8th grades) (Lehner 2017).

Similarly, the Ministry of Education of Portugal prepared the “The Student’s Profile for the 21st Century” document (approved in 2017) as a guide for strategies, methodologies, and pedagogical-didactic procedures to be used in teaching practices with the aim to clarify what is intended for young people as citizens when leaving compulsory schooling (Martins de Sousa 2017, p. 4).

Likewise, the Lithuanian MoE approved the “Students’ Computer Literacy Standard” that includes the ability to work with computers and the skills to apply IT in learning and obtaining general digital skills. Additionally, the Ministry approved “The requirements for the Pedagogues’ Computer Literacy Programme” that are compulsory for all teacher professional development programs to obtain both technological and educational ICT application competences (Brazdeikis 2017).

At a wider level, Japan MEXT works to gain public understanding of the effects and necessity of educational investment, as an investment for the future, in order to create a rich and fulfilling life for everyone and a secure society with

continuous growth especially focusing on **social competencies** for survival based on three principles of “independence,” “collaboration,” and “creativity.” Thus MEXT has promoted various plans for collaboration and cooperation between communities and schools, also enhancing lifelong learning opportunities (MEXT 2016).

Lithuanian policy focuses also on national welfare and aims to raise a young independent and innovative generation that will lead the country. To this end, goals (such as establishing an educational teachers’ community, effective interaction among stakeholders in education, accessibility and a long duration of education, and equal possibilities to all learners ensuring the system of incentives and equal conditions of lifelong learning opportunities establishment) for the national education system were set out in the key national strategic documents: “Lithuania’s Progress Strategy ‘Lithuania 2030,’” “National Progress Programme 2014–2020,” and “State Education Strategy 2013–2022” (Brazdeikis 2017).

In order to meet the challenges that are posed by wide-ranging and rapid changes in society, a revision of the national curriculum in Norway was initiated. It focuses on in-depth learning, new knowledge, and continuous skills acquisition. While the core curriculum consisted of reading, writing, oral, numeracy, and digital skills, it will be extended by three cross-curricular topics, sustainable development, democracy and citizenship, and health and life skills (Søby 2018). Moreover, digital skills (digital tools usage, critical thinking, technological understanding, basic skills, and social skills) are defined in the “Framework for Basic Skills” and in the curriculum for each separate subject, also within the digitalization strategy “Digitaliseringsstrategi for grunnsopplæringen 2017–2021” for primary and secondary education for 2017–2021, published by the Norwegian Ministry of Education.

Similarly, the Council for Informatization of Education in the Polish Ministry of National Education initiated a curriculum revision for computer science education to cover all school levels across grades K to 12. The curriculum has

three parts: unified aims (understanding and analysis of problems; programming and problem-solving; using computers, digital devices, and computer networks; developing social competences; observing law and security principles and regulations), purpose of study, and attainment targets. In order to encourage and motivate students to make personal choices, some optional attainment targets (freely added to a subject syllabus or assigned only to a group of students) are involved in the curriculum. Based on this new curriculum, informatics is a compulsory subject in primary schools (grades 1–6), middle schools (grades 7–9), and high schools (grade 10) and is an elective subject in high schools (grades 11–12); students may graduate in informatics when taking the final examination (Syslo and Kwiatkowska 2015).

In such policies and guidelines, computational thinking is a concept that plays an important role in future curriculum adoption. The vision for the development of capacities associated with computational thinking and digital literacy to foster cross-curricular competencies was presented in Portugal project - “1st cycle Primary School Programming Initiative” (Martins de Sousa 2017, p.12). Additionally, Portugal has started an initiative to create ICT as a subject from the 5th to the 9th grade; currently it is available in grades 7 to 8. ICT is defined as a subject with the aim to foster a learner’s critical analysis of information and to develop the ability to research, process, produce, communicate, and collaborate through technologies (Martins de Sousa 2017, p. 22).

A focus on digital competence assessment is planned in France from September 2018 across primary schools to universities. “The Common Framework of Digital Skills” modelled on the DigComp (“The Framework for Developing and Understanding Digital Competence in Europe”) will replace the “B2I” (The Internet and Information Technology Proficiency Certificate) created in 2001 (Terrades and Chibani 2018, p. 13). Since it includes notions of basic/independent/proficient users in different domains, it is intended to enhance the future employability and mobility of today’s students. Similarly, the Lithuanian MoE developed a law on digital literacy for primary and

secondary education based on “DigComp 2.1: The Digital Competence Framework for Citizens with eight proficiency levels and examples of use” and for teachers’ education based on the “DigCompEdu: European Framework for the Digital Competence of Educators” (Order No. V-598 2018).

Curricula Content

The content of the various computing-related curricula is quite different across countries. However, there are details in common. The majority include digital competence or digital literacy frameworks. For example, digital competence plays a fundamental role in Portugal where ICT is taught as a subject in grades 7–9 (Martins de Sousa 2017, p. 22). Some countries have a clear emphasis on the information processing area or a focus on programming (France, South Africa). By contrast, the CS curriculum in Austria covers basic competencies in dealing with technologies such as Microsoft Office products or descriptions of learning about basic principles of automata, algorithms, and programs (Spieler et al. 2017).

In Australia, digital technologies comprise three related strands:

- Digital systems (identify and explore digital systems (hardware and software components) for a purpose)
- Data and information (recognize and explore patterns in data and represent data as pictures, symbols, and diagrams; collect, explore, and sort data, and use digital systems to present the data creatively; independently and with others create and organize ideas and information using information systems, and share these with known people in safe online environments)
- Creating digital solutions (follow, describe, and represent a sequence of steps and decisions (algorithms) needed to solve simple problems, explore how people safely use common information systems to meet information, communication, and recreation needs) (AC DT Structure 2018a)

Additionally, the key concepts of abstraction, data collection, representation and interpretation, specification, algorithms, and development correspond to the key elements of computational thinking (AC DT Learning in Digital Technologies 2018b).

Finland’s new national curriculum has a clear emphasis on computational thinking. The central aims of the new curriculum are to develop the school culture and to promote instruction with an integrative approach. Thus pupils will be able to understand and combine knowledge and skills from different subjects and collaborate (Finnish National Board of Education 2016). ICT competences will be assessed as a part of subject-based assessment; no separate grades or certificates will be given (Kimmo 2017).

In France, computer science covers algorithms, machine, language, and information concepts that were used as a framework for the ISN (Informatique et Sciences du Numérique/IT and Digital Sciences) syllabus, which is accordingly structured into four themes: data representation, algorithmic, languages and programming, and computer architecture (Baron et al. 2014). These themes characterize computational thinking. There is no separate ICT subject in France; however, it is included in EMI (Education aux Médias et à l’Information – Education for Media and Information Literacy which integrates the notion of critical thinking) and an optional subject called ISN that includes computer programming, e-safety, accessibility, and algorithms. Additionally, education for media and information literacy is part of the curricula in lower secondary schools that enable learners to understand and use media, tools, and digital resources independently and in compliance with the law, such as protection and respect for privacy, intellectual property – controlling one’s image – and responsible behavior (Terrades and Chibani 2018).

Although Finland does not have an autonomous CS curriculum, the core curriculum describes seven transversal competences (construction of knowledge, skills, values, and will) that include ICT competence and multi-literacy. It also provides for teachers the criteria

for assessment at the end of grade 6 and the final assessment in grade 9. It is believed that this assessment supports pupils as lifelong learners (Finnish National Board of Education 2016). The necessity to adopt to the digital world can be seen in current Spanish educational law. According to this, ICT competence involves generic skills: creative, critical, and secure use of information and communication technologies to achieve objectives related to work, employability, learning, use of free time, inclusion, and participation in the society. Of course, it requires subject-related skills: textual, numerical, iconic, visual, graphic, and sound as well as their patterns of decoding and transfer. This involves knowledge of the main tools and also access to sources and information processing, as well as knowledge of the rights and freedoms of people in the digital world. The Spanish curriculum is arranged in subjects, and its main elements are the objectives, competences, contents, methodological approach, learning standards, and evaluation criteria, with reference to the “European Key Competences Framework” (Fernández 2015).

Similar topics in the English and Slovakian primary education informatics subject include information around us; communication via ICT; methods, problem-solving, and algorithmic thinking; principles of ICT; and the information society (Kabátová et al. 2016). Primary education informatics is identical to basic schools’ informatics. Furthermore, it contains the list of requirements for learners, such as the need to understand the concepts of CS; developing the skills to algorithmize an assigned task, collaboration, and programming skills; learning to comply with regulations on intellectual property; and developing their personality, creativity, and logical thinking (Bučková and Dostál 2017).

The documents discussed above clearly show that countries focus on digital age requirements, and to this end various strategies are applied in the education sector for its improvement. Some countries are following others’ examples, while some rely on international and/or local experts’ opinions. However, there are many issues to overcome in order to effectively and successfully implement all strategies. All responsible

authorities of education (at least in a country) must form one well-interconnected system with each owning their responsibilities and duties, such as curriculum and strategy developers, teacher trainers, and evaluators. Additionally, instruments and responsible authorities for measuring outcomes of computing education play an important role for education sector improvement: either by evaluating the outcomes for new strategy development or by providing good examples and tips.

Furthermore, despite England being one of the leaders in computing education, it still faces challenges, such as teachers’ lack of confidence in computing and CS as an overwhelmingly male-dominated subject and workforce; making computing education compulsory will not automatically lead to a higher proportion of young women choosing it (The Royal Society 2017).

Countries are redeveloping their curricula and guidelines in order to meet the demands of the digital age learner. However, to successfully implement all these policies, there are many factors to consider. For example, Korean education prepared a new computing curriculum, moving from computer education to informatics: “the focus on mere functional education on application software was reduced and contents on problem-solving methods and procedures, algorithms, and programming was strengthened with a view toward enhancing the understanding of computer science.” The adverse capabilities of computers spread, and content related to information ethics was reinforced (Choi et al. 2015). However, after ICT education guidelines were abolished, the selection rate of computer-related subjects dramatically decreased: less than 10% of middle and high schools offer informatics classes, and less than 5% of students have the opportunity to take an informatics class at school (Choi et al. 2015). Additionally, decreased time for elective subjects and absence of CSE evaluation are also reasons for the lower priority among elective subjects.

Korea evaluates students’ knowledge and competencies (listed in the curriculum) through written tests and their performance, respectively. The performance evaluation is usually weighted higher than the written test. They are also

planning to benefit from existing CSE evaluation studies, such as ICILS (International Computer and Information Literacy Study) that examines the outcomes of student computer and information literacy (CIL) across countries or TOPCIT (Test of Practical Competency on IT) that assesses the competency of IT human resources (Choi et al. 2015).

In Lithuania, the National Examination Center (NEC) is working in the area of computing education-based assessment. The maturity examination assesses students' skills grouped as follows: knowledge and understanding (lower-level skills); knowledge, technologies, and techniques application; problem-solving; and communication. Abilities to apply are weighted higher than other skill groups (it is 60% of the final evaluation). The content is based on the IT curriculum and involves four main activities: safe and lawful use of information and the Internet, working with text documents, processing of numeric information in a spreadsheet, and programming. Thus, students take written tests and performance tests (programming, documents management) (Order no.V-9 2018).

ICT and digital competence are integrated in all subjects in Norway. ICT-based assessment is offered in both lower secondary and upper secondary schools in Norwegian education (primary education has no centralized assessment). Some subjects offer a two-part examination in which the first part has no access to tools and the second part includes the use of ICT/internet (Søby 2018).

Curriculum and Country Features Summary

A summary of the country features of curricula discussed above concerned with computing education initiatives is presented in Table 1.

Computing Education and Teacher Training

Teacher training plays an important role in successful curriculum implementation. It is one of

three determinant factors in order for CS to meet the current needs of a digital society, along with curriculum adoption at different ages and the provision of sufficient technical and curricular resources for teaching staff (Cabrera-Delgado 2017). Teachers are the key people who implement and deliver curriculum to classrooms. Thus, Poland has developed CSE standards for teacher preparation, focusing on teachers' engagement in professional development and certification procedures for a teacher's work evaluation in order to support the teacher in better preparing for teaching CS (Syslo and Kwiatkowska 2015). Moreover, the experience in France shows that the administrative demands on teachers was one of the factors that led to a new discipline, i.e., informatics, to decline (Baron et al. 2014). Additionally, there was a lack of necessary knowledge for assessing students' competences, so teachers failed to successfully implement schemes for ICT skill certification proposed by the Ministry of Education of France in 2001. Nowadays, it is reported that there are many opportunities for French teachers to get support and certification in digital competencies development, provided by different authorities, such as the Higher Schools for Teachers, Ecole Supérieure du Professorat, and Regional Education Authority of Créteil, Académie de Créteil. Moreover, ICT in initial teacher education is compulsory (Terrades and Chibani 2018).

Many countries agree that teacher training is fundamental. Some have already implemented training courses; others are implementing new strategies such as "School 4.0. – Now it's digital": Austria's teachers are now offered an opportunity to attend qualification seminars for Microsoft Office Specialist and to obtain certificates for digital competencies and media competency in order to be able to pass them on to pupils (Lehner 2017). Previously, teachers were insufficiently trained for applied CS education because of the lack of programs for CS education in universities and the lack of the literature on practical, state-of-the-art examples for implementing CS education (Spieler et al. 2017). Similarly, in Ethiopia, the main challenge to deploy ICT in schools is to train teachers adequately and thus to ensure the quality of ICT education to make it accessible (Ethiopia (ICT)

Computing Education, Outcomes of, Table 1 Summary of intentions of computing-related courses

Country	Grade													Comments
	1	2	3	4	5	6	7	8	9	10	11	12	13	
Australia					M	M	M	M	M	M				CS subject (based on DT curriculum 2017)
Austria			M	M	M	M	M	M						ICT and informatics (based on School 4.0)
Ethiopia	A	A	A	A	A	A	A	A	A	A	A	A		ICT course
Finland													-	Integrated in other subjects
France													-	Integrated in other subjects
Germany	A	A	A	A										CSE standards drafts
Ireland													-	No planed changes
Italy													-	Digital education for all school levels (based on <i>digital education plan</i>)
Japan	M	M	M	M	M	M	M	M	M	M	M	M		Programing
Korea					O	O	O	O	O	O	O	O		As parts of other subjects
Lithuania	A	A	A	A										Informatics
Norway								O	O	O	O	O	O	Digital skills
Poland	M	M	M	M	M	M	M	M	M	M	O	O		Informatics
Portugal	O	O	O	O	O	O	O	O	O					Programing (primary school); ICT secondary
Slovakia														Integration of the DT in education based on MoE strategy 2020
Spain													-	CS improvement based on computer science education in Spain

Note: A available, M mandatory, O optional

Policy and Strategy 2016, p. 17). Consequently, students will develop ICT and higher level skills necessary for future employment in computer-related occupations in Ethiopia. Thus, Ethiopian government strategy is to update school curricula by including ICT courses, moreover to ensure ICT availability across all levels of the school system.

Teacher training and educational policy objectives can have direct interconnection. This is clearly indicated in Norway, where the government focuses on increasing teacher competence and improving the status and attractiveness of the teaching profession. To this end, the strategy “Promotion of the Status and Quality of Teachers– a joint effort for a modern school of knowledge” was developed with an idea to provide all students with the skills, attitudes, and values for life management, successful

participation in society, workplace, and community (Søby 2018). Additionally, pupils and teachers are required to use ICT across all school subjects at all levels of school (Røkenes Krumsvik 2016).

Conclusion

In order to successfully implement computing education, it is necessary to develop an appropriate system of policies, guidelines, teacher training, and evaluation with clearly defined responsibilities. Relevant support for teachers – training, infrastructure, and teaching content – is necessary. Additionally, understanding the pedagogies and assessment methodologies that underpin computing education will help teachers

improve pupil outcomes, and an adequate infrastructure for schools is crucial.

While policies mostly suggest the need to assess the skills or competencies of learners, there is a lack of models or clear assessment criteria and guidance for teachers showing them how to implement curriculum and how to assess students.

Cross-References

- [Algorithmic Thinking in Primary Schools](#)
- [Beginnings of Computing in School Education in Australia](#)
- [Computational Thinking](#)
- [Computing Curricular Report CE2016, A Summary](#)
- [Computing Curricular Report IT2017, A Summary](#)
- [Curricula in Computer Science](#)
- [Implementation of ICT in Secondary Schools](#)
- [Programming and Coding in Secondary Schools](#)
- [Teacher Education, Thinking About ICT](#)

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Computing Education, Practices in

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Synonyms

Computing education; Learning theories; Lessons; Practice; Teaching models; Theory

Introduction

Writing a contribution about practices of computing education is an intriguing but inherently challenging task, and an entire encyclopedia for itself could be elaborated on this subject.

One aspect of this endeavor is the abundance of teaching methods and approaches in classroom settings, and the other is, generally seen, the phenomenon of learning itself and in special teaching and learning in the field of computing. This is still far from being as settled and resting in itself as other traditional disciplines (e.g., languages, mathematics, science subjects, the humanities, arts, and music). As a consequence the following comprehensive summary cannot go into the detail of singular practices in classroom teaching but puts emphasis on an attempt to structure a very wide field without omitting its theoretical foundations.

In contrast to theoretical and prescriptive issues of computing education, including the wide field of teaching methods, rather little is known about what is really going on in classrooms during computing lessons.

The young school subject computing is still occupied with itself and the consolidation of its contents. With the still rapid changes, computer science teaching runs the permanent risk of dealing more with technologies and products than with the underlying educational content (Hartmann 2010). The role of the computer as a didactic medium on the one hand and computing

as a subject of instruction on the other is hardly kept apart, which makes it difficult to reach a common understanding on the subject and its differentiation from other subjects.

However, the computing curricula, educational standards, and reference frameworks currently being developed in many countries signal an increasing stabilization and clarity of content. Should these curricular efforts lead to a situation in which the school subject of computing can rest in itself without following every fad, this will not, however, mean the end of didactic approaches. The challenge for providing good practices in computing education and to convey a distortion-free and complete picture of the discipline will remain, and the focus will shift from “What and when to teach computing?” to “Teach how?”

What Is Computing Education?

Computing is the overall broad subject (area) and encompasses three related areas (Furber 2012):

- Computer science (CS) consists of theoretical concepts and practical skills, including the study of algorithms, coding, data structures, system architecture, and problem-solving, nowadays also embracing computational thinking.
- Information technology (IT) is industry related and deals with preexisting informatics systems (hardware, software, networks). IT helps us to solve a problem through appropriate choice, (re)use, and configuration of digital artifacts. It includes the use of technology in many fields as science, business, health care, and creative arts and requires good knowledge about IT systems, human factors, design issues, project management, and so on.
- Digital literacy (DL) can be defined as the skill which we might expect any school leaver to have just as reading, writing, and calculating. Covering competences (skills and knowledge) to use computers safely and effectively, DL can be seen as a required cultural technique to extend natural human abilities. It does not replace traditional reading and writing skills,

but it does build upon them. DL is the ability to understand, assess, evaluate, transform, and create information using digital media.

In order to illustrate these areas, the following questions may be asked when considering the task “creating and publishing a web page” (Simmons and Hawkins 2015):

CS: What is HTML? How is HTML rendered as a web page? How does a web page find its way from the client to the server? What is the essence of Cascading Style Sheets, and where can you find this concept in other application software?

IT: How do you host web pages; what hardware and software are needed? How do I choose the best software to make web pages? How do I choose and optimize graphics for quality and fast download?

DL: What are the steps to create a web page using a software package? How do I edit text and graphics? How do I include a video?

Theses on Contemporary Practical Computing Education

Modern information and communication technologies have a lasting impact on the lives of young people and demand new, far-reaching skills in dealing with digital media and information processing technology. They are of central importance both for the individual to cope with life and social participation and for the future viability of every country. But what is modern computing teaching and learning about (Breier and Alisch 2014)?

Computing Education is:

1. General Education

Aims and contents are always a reflection of political and economic conditions. Nature sciences have developed their full recognition comparatively late in the end of the nineteenth century. Laws of nature were discovered over material and energy. Today computer science forms the core of the next digital revolutions and is the basis of contemporary and future technologies, impacting our society. Computer science as a science and the subject computing as its educational mirror play a key role in automatic and

increasingly autonomous information processing and knowledge representation (GI 2000).

2. Information-Oriented

In modern computing lessons, information is at the center as the third basic quantity of nature; it can probably be distinguished from the other two quantities, matter and energy (Aßmann and Ungerer 2011). From the point of view of general education, the information-oriented pedagogy approach puts teaching computing close to the classical natural science subjects and justifies its implementation to the mathematical-scientific-technical area. Computing education is not primarily limited to the operation of devices and software in selected applications, but students acquire background knowledge about the basics, methods, applications, working methods, and the social significance of computer science systems. In addition to information, communication, cooperation, model, algorithm, computer science system, language, and automaton are further guiding concepts of information-oriented teaching. In this understanding, computing builds bridges to the social and societal sciences and at the same time opens up to media education. Digital media themselves become the subject of teaching.

3. Competence-Oriented

Competence orientation puts the outcomes and results of learning into the foreground action, practically applicable and of personal and social significance. In the educational plans on which modern computing education is based, the competences to be acquired by the pupils can be aligned to educational standards. The principles and standards for computer science in schools recommended by the GI in 2008 (GI 2008) provide a suitable basis for this.

4. Context-Oriented

Contemporary computing teaching uses innovative teaching concepts such as IniK (Informatik im Kontext) (Computing in Context, Diethelm et al. 2011). IniK is based on the assumption that solely technical computing competences do not suffice to understand

the digital world of IT systems and digital media and to be able to use them in a self-determined way. To this end, questions are placed at the center of computing that go beyond technical issues and include the social context, aspects of economics, culture, politics, or law (Coy 2005). Answering these questions makes it possible to develop IT content in a cross-disciplinary way and can lead to sustainable computing competences.

5. Media-Related

Contemporary computing teaching takes into account that computer science education and media education are two complementary, mutually dependent tasks of every school education. The fact that their fields of activity do not overlap is due to the nature of new digital media. From a technical point of view, they are IT systems that consist of hardware and software and are linked to the Internet as the leading medium.

Today, the contribution of computing and media education no longer lies solely in the provision of basic computer methods but also in the fact that digital media themselves become the subject of computing teaching and that pupils acquire simultaneously media competence. This is possible through an appropriate selection of contexts (cf. thesis 4). Typical comprehensive topics could be:

- E-Mail (only?) for you.
- My computer is talking to me!
- Smart and rich through apps.
- Cyberbullying.
- Social networks.
- Don't trust a picture!
- Mobile Internet – always and everywhere reachable?
- Computer games – between fun and addiction among other things.

Some of these have already proven their value in class and have shown that they are particularly appealing to schoolgirls.

6. Gender-Sensitive

Gender-sensitive teaching computing is characterized by a learning environment which is equally suitable for pupils and encourages them to discover their own talents

and strengthen their self-confidence. Computing lessons take into account the fact that female pupils have on average less experience in using (desktop/laptop) computers (but not smartphones) than male pupils and ensure that these differences are not intensified but reduced. Contexts are helpful (see thesis 5) that especially appeal to girls. "One key, in our opinion, lies in the focus with which the study of the contents of computer science is taught. Experience shows that the majority of female pupils and students are not interested in technology 'in itself,' but in technology 'for what.' The application contexts and the design of technology in response to these motivate them to deal equally with technology and the contexts" (Schirmer 2013). It is precisely the design of technology and the creativity associated with it that take on special significance in gender-sensitive computer science teaching, as various studies indicate that women and girls can gain an interest in computer science with the help of creativity (Romeike 2008).

Furthermore, gender-sensitive computing teaching focuses on gender equality. For computer science lessons, gender equality means always tracking and breaking down the effects on pupils with regard to their outdated and "traditional" role attribution. To this end, teachers have to analyze tasks or IT projects from both gender perspectives. The projects should always contain attractive and creative elements for both sexes in equal proportions, so that both sexes can learn the necessary computing competences (modelling, implementing, etc.) within the respective subtasks.

7. Language Teaching

Languages play a very important role in computing teaching. Their conscious use offers many opportunities to build up sustainable linguistic competences, thereby different language levels (everyday, educational, technical). Language skills are systematically built up in computing lessons by giving pupils the opportunity to present complex interrelationships orally and in writing in a variety of ways.

Computing teaching supports the development of general language competence among pupils. Volker Claus recognized this as early as 1995. He postulated computer science teaching as language teaching and suggested that “the analysis and use of languages of all kinds, starting from computer science languages, should form the general core for the newly (1995) oriented school subject of computer science.” Computer science does not prefer any special language: norms, program sequences, drafts, specifications, etc. are presented in natural languages; algorithms, data structures, or objects are usually described in semiformal languages, mathematical calculations are used for theoretical questions and modelling, and programs must ultimately be formulated in an artificial language (Claus 1995).

8. Interdisciplinary

Lessons according to “Computing in Context” are per se interdisciplinary, subject-linking lessons. Assuming a real-life context, there are manifold references to different subjects. Probably only a few teachers are able to deal with multidisciplinary challenges with professional competence. Appropriate interdisciplinary teacher training in which colleagues from the relevant subjects join together to form a team may be the key. In interdisciplinary teaching, which must be mastered by a single teacher, the “courage to fill a gap” is recommended (Diethelm et al. 2011).

9. Project-Oriented

A pedagogical project “represents the joint attempt by teachers, pupils, parents, experts, etc., to connect life, learning and work in such a way that a socially relevant topic or problem can be dealt with within and outside the classroom, which at the same time corresponds to the individual needs and interests of teachers and pupils. The work and learning process triggered and organised by the project idea is as important as the outcome or product to be achieved at the end of the project. Projects open up the opportunity to remove the

socially prescribed separation of headwork and manual work to a certain extent” (Meyer 1987).

At the center of each learning project is an exemplary context, with which the pupils deal in a creative way and develop theoretical concepts and contents within these projects. The context is chosen in such a way that the pupils need to acquire competences from as many areas of competence as possible. When selecting the contexts, the students’ interests and performance as well as the perspectives already postulated in theses 4, 5, and 6 are taken into account. Teachers ensure that different learning interests are not ignored. If possible, the pupils will be involved in the selection process.

10. Binding for All Pupils

In the twenty-first century, digital competences have at least the same significance as competences in the classical natural sciences of biology, chemistry, and physics (cf. thesis 1). For a reliable implementation, computing teaching needs political commitments. The short history of schools gives evidence that without a subject computing in its own right, the systematic promotion of corresponding competences cannot be guaranteed.

Future generations will move in an environment that is largely shaped by information technology. By then at the latest, mastery of computer science methods and tools will be the fourth cultural technique alongside writing, reading and arithmetic. But this also results in a central, not only technical, but above all social task: namely to enable all people to handle their data in a self-determined way and to guarantee this. (GI 2006)

The future of computing lessons characterized in these theses requires a rethinking of politicians and teachers. Many countries are making already good progress in devising corresponding computing curricula and implementing the subject computing in schools. But there is still a long way to go in order to transform the theory of (necessary) computing education into good practices at classroom level.

From Curricula to Delivering Lessons

A curriculum can be seen as a contract between society, politics, and schools/teachers about the way of organizing and providing sequences of learning experiences aimed at producing desired learning outcomes. The curriculum reflects the kind of society to which we aspire. In the simplest terms, “curriculum” is a description of what, why, how, and how well students should learn in a systematic and intentional way. The curriculum is not an end in itself but rather a means to fostering quality learning (UNESCO 2013). Another definition describes the curriculum as all planned learnings for which the school is responsible and all the experiences learners have under the guidance of the school. Curriculum is the totality of learning experiences provided to students so that they can attain general skills and knowledge at a variety of learning sites (Marsh and Willis 2003). Put in the simplest way, a curriculum is a course or plan for learning (Taba 1962).

An ambitious attempt to put curriculum issues in a broader context, the “Darmstadt Model” has been developed for comparing computing education in different countries. Within these comprehensive model terminologies, goals and competencies, content issues, programming languages, assessment, and teacher education and trainings, also teaching conditions and practices are included.

This model shows impressively the complexity of implementation issues and the practices of computing education in a single country. Herein, “curriculum issues” are (only) one of 13 identified factors in the dimension “educational relevant areas.”

Inherently, every model has limitations, reduces complexity, and mirrors reality often only in narrow contexts. Curriculum issues and curriculum reforms cannot be judged without looking at the educational system, educational governance and the sociocultural background, and, as mirrored in the model, its range of influence.

Since some years, in many countries curricula are interwoven with competence models and

Computing Education, Practices in, Table 1 Typology of curriculum representations

Intended	Ideal	Vision (rationale or basic philosophy underlying a curriculum)
	Formal/written	Intentions as specified in curriculum documents/materials
Implemented	Perceived	Curriculum as interpreted by its users (especially teachers)
	Operational	Actual process of teaching and learning (curriculum-in-action)
Attained	Experiential	Learning experiences as perceived by learners
	Learned	Resulting learning outcomes of learners

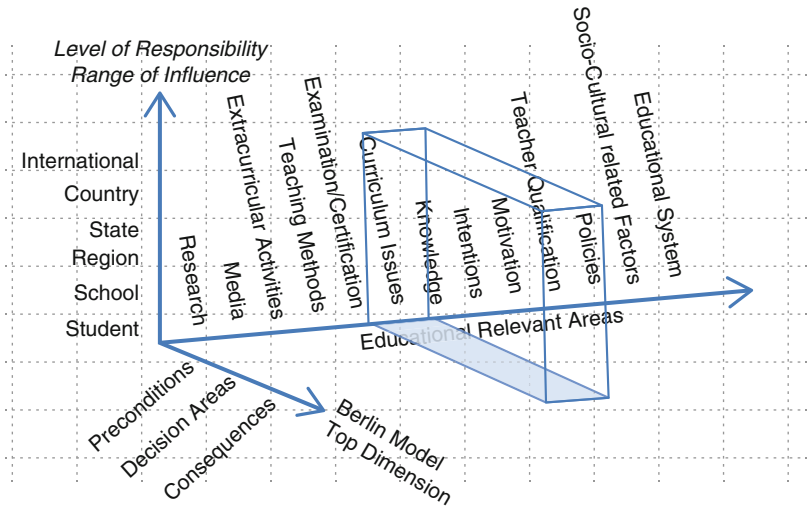
educational standards. Not least due to the disappointing results of international comparative studies such as TIMMS and PISA about 20 years ago, educational experts in many countries brought up the idea and concept of outcome orientation and educational standards.

There are different views on curriculum levels. The intended curriculum is content specific by the state, district, or school to be addressed in a particular course or at a particular grade level. The implemented curriculum is content actually delivered by the teacher, and the attained curriculum is actually learned by the students (Marzano 2003).

Table 1 illustrates the long way from the intended curriculum to its way into the brains of the learners where effective curricula with the status “attained” leave something magic called “competence” (Akker 2010). In extension to the Darmstadt Model in Fig. 1 and its axis “Level of Responsibility/Range of Influence,” a differentiation between various levels of “curriculum responsibility” could be useful when discussing computing education in view of curricular activities. These stages are top-down as follows: supra (international, comparative), macro (system, society, nation, state), meso (school, institution, program), micro (classroom, group, lesson), and nano (individual, personal).

Computing Education, Practices in,

Fig. 1 Darmstadt model (Hubwieser et al. 2015)

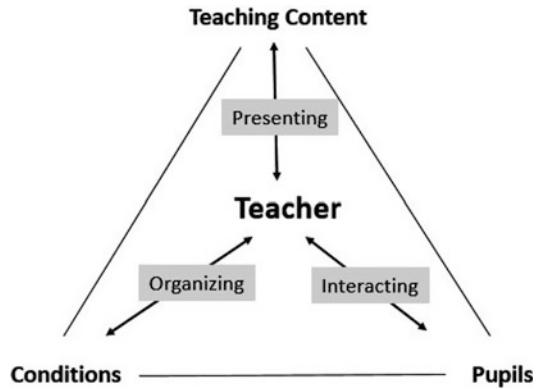


Clear objectives and measurable learning outcomes are at the core of the idea of competence orientation. This is represented by the top dimension “consequences” of the Darmstadt Model, whereas the operational and experimental stage can be subsumed under the “decision area,” the “battle zone” in the class where the curriculum meets pupils in concrete lessons.

Teaching Models

The majority of scientific contributions to computing didactics deal with subject-specific and content-related aspects. (Empirical) studies about practices of computing teaching are the exception, and aspects of teaching organization and the conditions of computer science teaching (media use, teaching materials, and teaching methods) are still a research desideratum. Despite its special position as a young, dynamic subject, computing undoubtedly obeys the logic of subject-independent teaching models in general, in which determining parameters become transparent by reducing the reality of teaching. Every didactic activity, both traditional and reformed, takes place between teachers and pupils who pursue teaching objectives based on selected themes (what should be learnt when?).

In the often quoted didactic triangle of relationships according to Herbart’s teaching theory



Computing Education, Practices in, Fig. 2 Teacher-centered model

(nineteenth century) “pupil-subject-teacher,” the complexity of teaching is only inadequately expressed. However, even a somewhat expanded model (Fig. 2) makes visible those structures that can be used to better reflect the reality of teaching. The perception of learning processes decisively shapes the understanding of the teacher’s role and thus the positioning, networking, and perspective in the didactic triangle. It is time to focus not only on the currently dominant content dimension but also on the actors in the teaching process, i.e., learners and teachers.

The key to good teaching is finding this balance between structure and agency, which is the great challenge of education. There is a constant

tension between agency (what learners do) and structure (how the context is constrained).

A look beyond the boundaries of computing didactics to physical education (sports) as a teaching subject suggests the extended teaching model shown in Fig. 2. This puts the teacher at the center of the teaching. *Prima facie* directed against the mainstream of constructivist learning theory, this model (Scherler 2013) makes sense, especially in view of the similarities between sports and computing teaching. In both subjects, special equipment (media) and teaching conditions play an important role. Scherler stresses the coherence and fits concerning the interdependencies presentation (content), organization (conditions), and interaction (pupils). Presentation, interaction, and organization have to be coordinated as well as possible, which fall under the sole responsibility of the teacher and have an influence on the quality of the teaching. The more freedom that teachers offer learners, the more they need to think about the constraints of the established learning environment.

In order to teach better, we need to understand the students' thinking. Teachers often fall into the expert's trap to assume too much prior knowledge and to fail to make explicit the knowledge that is implicit to experienced teachers. Good teachers can predict the pupils' misconceptions. Research confirms that "students' scores showed the most improvement when teachers were able to predict their students' wrong answers" (Reuell 2013).

Rather than thinking like an expert, it is necessary for teachers at the lesson planning stage to think like a novice.

Teachers need to have an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different stages and backgrounds bring with them... if those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners.

The most effective teachers have deep knowledge of the subjects they teach, and when teachers' knowledge falls below a certain level, it is a significant impediment to students' learning. As well as a strong understanding of the material

being taught, teachers must also understand the ways students think about the content, be able to evaluate the thinking behind students' own methods, and identify students' common misconceptions.

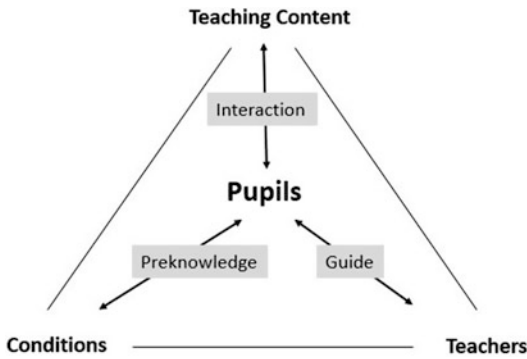
Computing does need explicit teaching and subject-specific pedagogy. Findings in cognitive psychology are the key to improved learning as a result of certain teaching practices.

Extensive research recommends that a curriculum needs to be spaced and interleaved and should include frequent practices (Lau 2018). Further a curriculum is best structured around problems to be solved, and a good way to frame lessons is through carefully designed fertile and deep questions.

Based on the comprehensive theory of instructional design, there are ten research-based instructional principles that teachers should use (Rosenshine 2012):

1. Lesson starts: Begin a lesson with a short review of previous learning (low-stake testing, questioning to address misconceptions, etc.).
2. Present new material in small steps with student practice after each step.
3. Ask a large number of questions and check the responses of all students.
4. Provide models.
5. Guide student practice.
6. Check for students' understanding.
7. Obtain a high success rate.
8. Provide scaffolds for difficult tasks.
9. Require and monitor independent practice.
10. Engage students in weekly and monthly reviews (exit tickets, low-stake quizzes, summative assessment).

The structurally identical, but with regard to the distribution of roles learners/teachers modified, model places the learner at the center of the teaching process. Here the teacher acts as a teaching companion or learning designer and catalyst, who also explicitly considers the methods, teaching materials, or media (how is learning done?) and is responsible for the learning conditions. This learning arrangement is the basis of the



Computing Education, Practices in, Fig. 3 Pupils-centered model

“new tube” of research-discovering learning in the classroom, with which “old informatic wine” comes or should come into the heads of teachers and students (Fig. 3).

Students do learn cognitive processes through experience and the failures they are making, finding and avoiding them, and trying not to repeat them. When they avoid an error that they know they have made previously, they can say that they have learned.

They learn by doing, that is, they learn from thinking about those experiences. When they have understood the experiences well enough, students can (unconsciously) index them so that they will come up again just in time when they need them again. Students do not learn from memorizing answers. They learn from developing questions for themselves that they then can begin to find answers to (Schunk 2011).

Learning Theories

Behaviorism

The principles of this theory can be found in schools with positive discipline systems that seek to modify behavior through rewards and sanctions. In computing, game-based learning can create similar results when players are rewarded for correct answers. Many quiz (responsive) systems can be assigned to this learning

theory which goes back to the famous Pavlov’s experiments involving dogs, food, and bell ringing.

Cognitivism

Piaget identified cognitive development structures whereby individuals create their own internal knowledge structure (schema) and then attempt to classify new information into the existing schema (assimilation) or develop new schema if it does not fit within the existing structures (accommodation). Cognitivism is primarily concerned with the way in which learners gain knowledge. This is usually fundamental in the computing field as the ability to create and manipulate knowledge is at the core of what the learners do. Effective tutoring systems are based on this theory.

Constructivism

Individuals construct their own knowledge. A person’s interpretation of knowledge is influenced by their experiences, environments, and beliefs.

In the classroom, the constructivist view of learning implies various teaching practices. It usually means encouraging students to use active techniques (simulations, experiments, real-world problem-solving) to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing. The teacher makes sure he/she understands the students’ preexisting conceptions and guides the activity to address them and then build on them (Oliver 2000).

Constructionism

It builds on constructivism by suggesting that individuals construct particularly effective mental models when they make a meaningful product. Coined by Seymour Papert, the term was particularly applied and investigated through IT-mediated learning. Nowadays constructivism closely connects with the ideas of playful and problem-based learning. Block-based programming environments as Scratch, App Inventor, and the Maker Movement are based upon constructionist principles.

It is plausible that different types of learning match to different appropriate learning theory approaches.

Introductory Learning

Learners have little directly transferable prior knowledge about a skill or content area. They are at the initial stages of schema assembly and integration. At this stage classical instructional design is most suitable because it is pre-determined, constrained, sequential, and criterion-referenced. The learner can develop some anchors for further exploration.

Advanced Knowledge

Acquisition follows introductory knowledge and precedes expert knowledge. At this point constructivist approaches may be introduced.

Expertise Knowledge

Acquisition. In this stage the learner is able to make intelligent decisions within the learning environment. A constructivist approach would work well in this case.

This is a rule of thumb, and it is still important to consider the context before recommending any specific methodology.

Planning and Structuring Lessons

Lesson planning is likely to have the greatest impact on teaching and learning. The crucial point is aligning the teachers' subject knowledge with their pedagogical content knowledge. As teachers learn how to best teach their subject, they will continue to develop their pedagogical content knowledge both consciously and subconsciously. They will find out what works and what does not work. Shulman, who coined the term "pedagogical content knowledge" (PCK), refers as follows:

Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of

representing and formulating the subject that make it comprehensible to others. Since there are no single most powerful forms of representation, the teacher must have at hand a veritable armamentarium of alternative forms of representation, some of which derive from research whereas others originate in the wisdom of practice. (Shulman 1986)

Instructional design is the science of creating instructional curriculum that is geared toward producing specific learning outcomes, based not only on pedagogical research but also on current instructional practices. Instructional design is useful in producing effective lesson planning and designing (computing) courses. While the implementation of certain technological resources can enhance and enrich learning outcomes, the end goal is effective instruction, not the production of technology-rich materials. In essence, then, the role of instructional design is to create instructional experiences that facilitate the acquisition of knowledge in a way that is not only efficient but effective and appealing to learners. As a framework for developing learning modules, the focus of instructional design is on enhancing the learning acquisition process with the goal of engaging, encouraging, and motivating learners to gain deeper, more significant, and more meaningful levels of understanding and knowledge. This cooperative and collaborative method makes students dependent on each other to succeed and fosters in the best case social learning.

Dimensions of (Computing) Lessons

In general, there are four major components to be considered when creating any form of course or learning activities and lessons:

Learning tasks – ensuring skills, knowledge, and attitudes are covered in sequential ways, moving from easy to difficult, using, when appropriate, so-called real-world tasks, reducing scaffolding with each subsequent task and varying form of practices
Supportive information to accompany them – bridging links between tasks, explaining how

to approach problems and questions, offering strategies to consider, and showing how the domain (the big picture) is organized

Procedural information to accompany them – what is needed before tasks can be attempted, what should be practiced, how to undertake any routines needed, and any step-by-step instructions needed

Part-task practice – providing more practice tasks so learners can gain a level of automaticity in undertaking them, offering repetition, once a real-life task has been completed (Passey 2015, cit. Van Merriënboer and Kirschner 2012)

The underlying educational questions of curricula down to concrete everyday lessons are who should learn something from whom, when, with whom, where, how, with which means, and what for. Based on these basic fundamental questions of general pedagogy, six dimensions can be distilled for every lesson planning. Between all these dimensions, there are mutual interdependencies. Results of studies show that learning goals on a theoretical level play a central role for teachers and that goals and objectives should be the starting point for all planning considerations (Fig. 4).

Content and Objectives

It is self-explanatory that “content is king” – an often cited quote in the world of online marketing – applies also to subject learning when it comes to education in formal settings.

In Fig. 5 an attempt is made to allocate content to the three strands of computing education (Lau 2018, p. 4). But education refers also to social learning which can be influenced and supported by student-centered cooperative teaching methods.

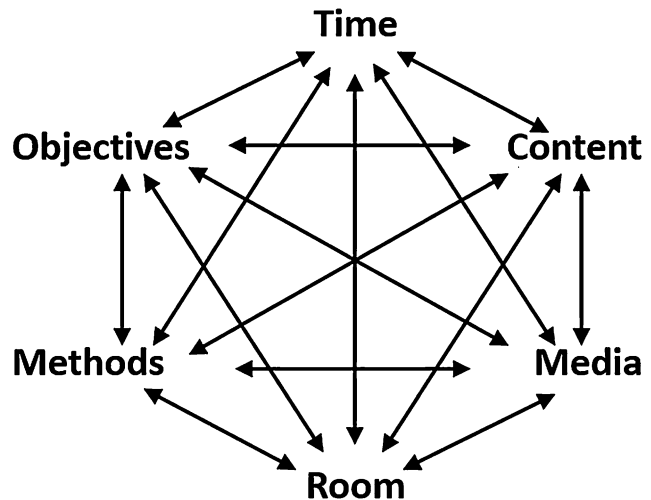
Most (old) curricula were centered around an age-appropriate structured body of subject-specific content. Nowadays, competence- and outcome-oriented curricula and syllabi define in different granularity general goals and detailed objectives as well.

In computing lessons concept and product knowledge, competences and skills are imparted. For the learners (and sometimes also for teachers), the main goals of their teaching stay often unclear. They are in danger to get lost in details.

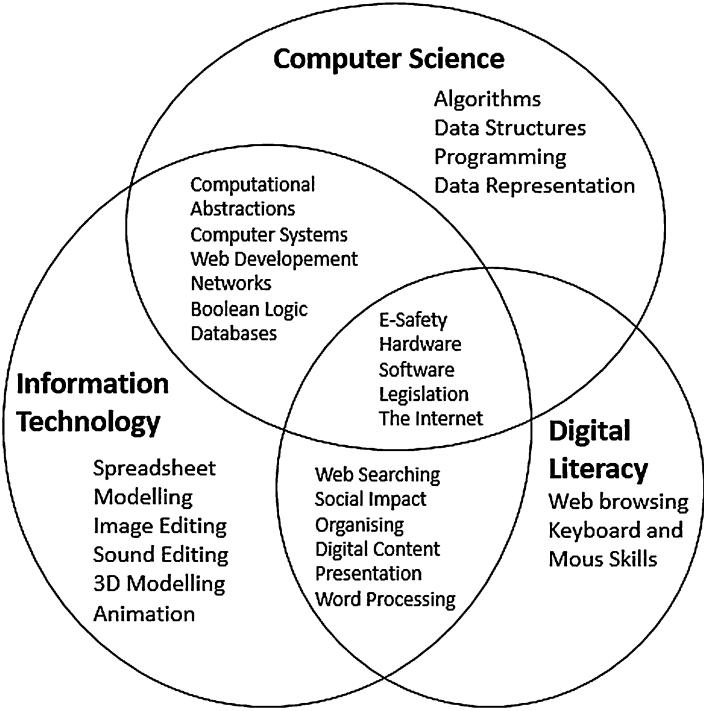
Clearly formulated goals help them to keep an overview of the field (Hartmann 2006).

One seminal work about the classification of objectives is the Taxonomy of Educational Objectives (Fig. 6. Anderson and Krathwohl 2001).

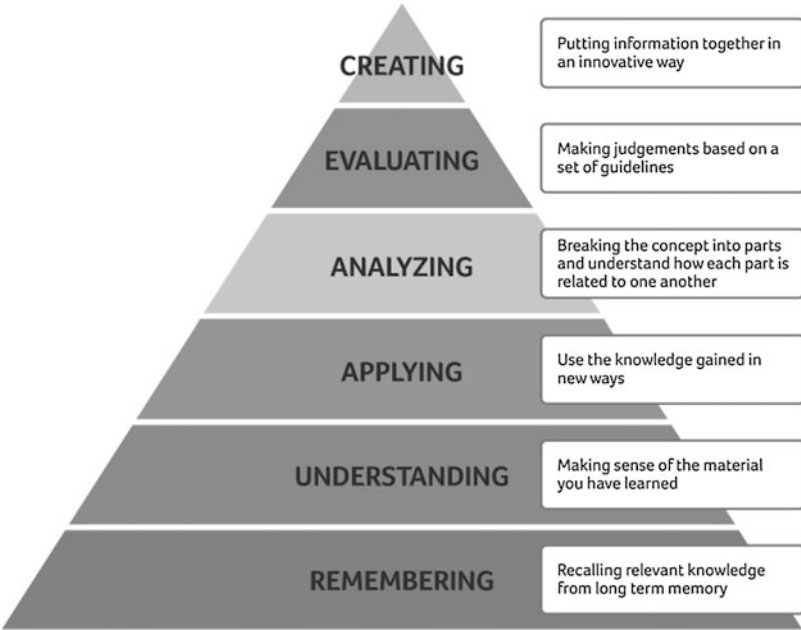
Computing Education, Practices in, Fig. 4 Six dimensions of lessons



**Computing Education,
Practices in,**
Fig. 5 Computing –
programs of study



**Computing Education,
Practices in,**
Fig. 6 Taxonomy for
educational objectives



(Teaching) Methods

The content of a subject determines what method to be used to achieve effectiveness in the teaching and learning process. Subjects definitely require different teaching methods that suit such disciplines. Computing can be also taught with inquiry or discovery methods, while the lecture method can be used in some art subjects depending on the specific content of the particular subject.

The instructional objectives a teacher intends to achieve at the end of a lesson determine the choice of teaching method to use in teaching the subject.

The four cornerstones of the decision-making field described in Fig. 7 are ideal-typical exaggerations of the repertoire of teaching methods. They represent fundamental perspectives. They are not models for planning and designing real lessons. Such models are multifaceted modifications and additions of the four basic patterns:

An exclusively instructive lesson is just as unthinkable in school reality as a purely discovering lesson in completely teacher-directed lessons is, apart from special situations, as unrealistic as completely autonomous learning. The reality of effective teaching lies between the four cornerstones of the methods.

Every well-founded lesson preparation requires guidance by the teacher, even if a more autonomously discovering lesson method is pursued. No teaching model can be classified unambiguously in the context of the decision-making field. This applies above all to methods that work in a longer time horizon: Within the framework of a project or a didactic work, guided or autonomous elements can be used, depending on the topic.

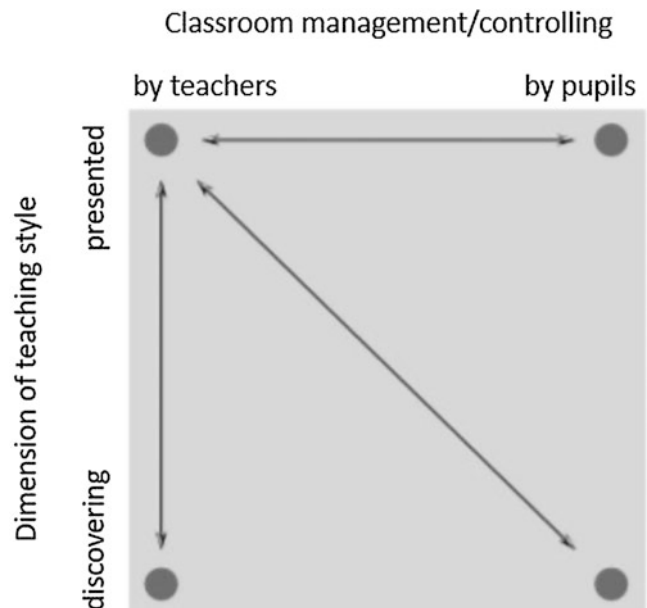
The teaching of student groups requires decisions in order to determine the most meaningful social form for the different teaching phases.

The realization of an effective lesson requires a high degree of flexibility in order to be able to respond to the constantly changing conditions of a school lesson. In addition to the necessary pedagogical skills, one needs the knowledge to master special “critical” situations, as they are typically associated with the respective teaching methods.

The best teaching method is the one that your students respond to. Good teachers adjust their methods in response to their pupils’ ability to learn the material being presented. Good direct instruction is still a very effective method especially when working in introductory courses.

The following suggestions are made for effective use of teaching methods in the teaching and learning process:

**Computing Education,
Practices in, Fig. 7** Basic
patterns



1. Teachers should know the nature of the subject matter to be taught and be conversant with it to enable him/her to determine the most suitable teaching method/methods to use in a given lesson.
2. The instructional objectives a teacher intends to achieve by the end of the lesson determine to an extent the type of teaching methods. Teachers should try to match the instructional objectives to suit the teaching methods to be chosen for a lesson.
3. The teacher must be very familiar with the type of teaching methods he/she wants to use at any given time and must ensure it is most appropriate for the success of the lesson.
4. The teacher must consider the age, interest, etc. of the learner and ensures the right teaching methods and materials that will suit the learners are in place.
5. In choosing appropriate teaching methods, the teacher is encouraged to consider the time to be used for a lesson, as this will go a long way to determine also the type of teaching methods to use.
6. The teacher should put into consideration the population of the class, the environment, and the size of the class. This will help to determine

a most suitable teaching method to use for a lesson and make it worthwhile.

Within the plethora of teaching methods, there are some which meet the requirements of computing lessons better than others.

Task- and Problem-Based Learning

One approach to plan a scheme of work for computing lessons is centered about tasks and problems.

Task-based learning is a teaching method for short lesson sequences. Already covered and understood subject matter and solved tasks can be deepened by extended tasks.

One special type of tasks is so-called Beaver tasks which are the constituent part of the Online Bebras Contest which takes place every year in over 50 countries worldwide (2018), reaching almost 3 million pupils. These short tasks, each of them with a strong, but for many pupils hidden, computing background, can be solved “unplugged” through (computational) thinking (Dagiene and Stupuriene 2014).

Since 2014 more than one thousand Beaver tasks are publicly available and can be used as starting points for many computing activities (Fig. 8).

**Computing Education,
Practices in,**
Fig. 8 Digital broken
clock

On a digital clock, each digit can be formed by lighting up some of the seven segments.



Below, each of the digits from 0-9 are shown by lighting up some of those seven segments.



What is the largest possible number of segments that are not working.
0, 1, 2 or 3?

Beaver tasks are computational puzzles and therefore ideally suited for activating the brain, looking for solutions by logical reasoning and associative thinking, and having fun in case of finding the correct result.

Computer Science Unplugged activities (also known as CS Unplugged) are a problem-based approach without requiring students to use a computer (Bell and Newton 2013). An impressive example is the “parity trick,” which is presented as a magic trick, based on the concept of error-correcting codes (Fig. 9).

Problem-based approaches structure students’ activities more by asking them to solve specific (open-ended) problems rather than relying on students to come up with their own problems in the course of completing a project, an approach which is the prerequisite of project-based learning.

Another seemingly similar approach is quest-based learning; unlike project-based learning, in questing, the project is determined specifically on what students find compelling (with guidance as needed), instead of the teacher being primarily responsible for tasks.

Discovery or Inquiry-Based Learning

This approach of learning is a vaguely defined generic term for several methodological

variations according to the degree of the teacher’s involvement. In structured and guided inquiry-based learning, the teacher provides the pupils with methods, tools, and materials. The pupils should discover and develop their own approaches and problem-solving methods as independently as possible or as part of a team. In (totally) open discovery learning, the teacher withdraws almost entirely. The pupils find their own research topic themselves and work on it independently.

Inquiry-based learning is basically a pedagogical method, developed during the discovery learning movement of the 1960s as a response to traditional forms of instruction where people were required to memorize information from instructional materials, such as direct instruction and rote learning. The philosophy of inquiry-based learning is deeply rooted in constructivist learning theories, such as the work of Dewey (1997).

Learning by Doing

Action-oriented teaching in form of physical computing and robotics within the worldwide Maker Movement is still gaining pace in computing education, although not part of everyday computing yet. Research shows that this approach is very popular among pupils (Bartel 2000). Among



Computing Education, Practices in, Fig. 9 Unplugged parity trick (open house day in an Austrian school)

about many other teaching methods and approaches, “devising practically functioning” ranks in the first place, leaving methods as group work, learning by teaching, pair programming, and discovery learning behind.

Media and Tools

Talking and writing about practices of computing education and not mentioning at least some of digital software tools and digital devices, used in computing lessons, would be a gross negligence. All abovementioned learning theories can be assigned to digitally and technologically enhance computing learning. It is evident that the vast majority of everyday computing lessons do make (heavy) use of informatics systems and digital devices (hardware in different forms), learning platforms, standard and development software, as well as social media, assessment tools, and open educational resources (Passey 2015; Anderson 2013).

Time and Room

The time allotted to a subject on the school timetable must be taken into account when determining the choice of teaching method. Time-consuming methods like the abovementioned group puzzle, role-playing, station learning, or complex simulations can be done within double periods. When there is little time to execute a considerable scheme of work, then direct instruction is appropriate, having the mental capacity of learners in view.

Especially in computing lessons, the classroom environment can have a great influence on students’ performances and outcomes. Classroom layouts in computing classrooms (computer labs) need to be carefully designed considering having separate tables in the middle of the room for planning and theory work.

Classroom environments set a tone for learning and cause learners to behave in certain ways. It is important to consider the classroom environment in selecting an appropriate teaching method for a lesson. The space available in a class, ventilation, illumination, and other teaching devices in a classroom, etc. all these affect the choice of teaching methods to be used.

Concluding Remarks

Practices in computing education in schools and formal settings in classes and classrooms comply with the same conditions, habits, and routines as in other subjects. Accordingly, successful computing education depends also on good classroom culture and behavior management, on a sound lesson pace and differentiation, and not least on appropriate assessment methods, marking, and feedback strategies.

Cross-References

- ▶ [Computational Thinking](#)
- ▶ [Computers in Secondary Schools, Educational Games](#)
- ▶ [Computing Education, Outcomes of](#)
- ▶ [Curricula in Computer Science](#)
- ▶ [Problem-Solving in Computer Science, Learning from a Gifted Peer](#)
- ▶ [Programming and Coding in Secondary Schools](#)
- ▶ [Teacher Education, Thinking About ICT](#)
- ▶ [Teaching about Computing](#)
- ▶ [Teaching and Learning Computational Thinking and Coding Skills](#)

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Control Technology and School Curricula in the Late 1980s in Australia

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Synonyms

Machine control; Mechanized systems; Robots

Introduction

The term **Control Technology** can be defined as “an application involving the use of a computer, with the aid of suitable interfacing and software, to give its user control of some external process” (Tatnall and Tatnall 1987). Examples of control technology include devices such as robot vehicles and “turtles” (The Turtle was an early robot used in education by Seymour Papert), robot arms, industrial robots, equipment to monitor and control scientific experiments, process control equipment, computer numerically controlled lathes, and other automated machines (Tatnall 1990).

Although there had been some examples of control technology in schools before this, in some schools in Australia, it began to be treated seriously as an addition to secondary school curricula in the mid-late 1980s, and in primary schools a few years later. Although not many schools made use of control technology at the time, it was generally recognized that an understanding of the principles of machine control and how technology actually works, of what robots could and could not do, and why they were being introduced in factories should be an important and relevant part of secondary education. The first question that was asked by educators, though, concerned the benefits that learning about (and with) this material would be to students. The question then became, at what school levels did the *content* of a course on control technology become important, rather than just *use* of this technology in the process of problem solving? (Tatnall and Davey 1986). One practical concern was the extent to which many teachers felt comfortable in using this technology.

Mechanized Systems

In studying mechanized systems, three fundamental elements need to be considered: power, action, and control. The first two belong to the realm of mechanical engineering, but control is related closely to computing. We can consider several levels of control: uncontrollable, operating under

human control, using automatic control and involving full automation. Control technology is concerned with automatic control and with full automation. A device cannot properly be considered to be a robot unless it is automated and can be programmed to perform more than just a single task. Hence, robotics is a hybrid of mechanical engineering and computer science. The term *robot* comes from “Rossum’s Universal Robots,” a 1920 play by Karel Čapek (1920) and *robotics* or the study of the use of robots was popularized in the 1950s by the science fiction writer Isaac Asimov (1950).

Control Technology Learning Materials: Late 1980s and Early 1990s

While not a complete list of those technologies available at the time, some of the most useful materials for senior secondary school courses in control technology were:

- LEGO Technic Control and LEGO Logo. This consisted of LEGO bricks, the LEGO manual control unit, LEGO control interface, interface cards appropriate for a variety of microcomputers available at the time (including Apple // e, BBC, Commodore 64 and IBM-PC (compatible) computers), software, and instructional materials. LEGO Lines and LEGO Logo programming languages were available (Carter 1988; Harvey 1985; LEGO 2018).
- Fischertechnik Robotic Computing Kits. Like LEGO, these contained building bricks, interfaces, software, and instructional materials and could be used with available microcomputers (Fischertechnik 2018).
- The Tasman Turtle. This LOGO-based educational robot had speech recognition and synthesis, electronic compass, touch sensors, drawing pen, motion control, and an infrared interface (Denning Branch International 2005).
- Trekker Robot Vehicle (from Clwyd Technics, Wales). Trekker was a completely built-up robot vehicle very well equipped with touch,

magnetic, ambient light discrimination, and contrast light discrimination sensors (Centre for Computing History 2018).

- Special devices such as robot arms, computer numerically controlled (CNC) lathes, and equipment for measurement and monitoring of scientific experiments.

Teachers reported that some of these technologies were, however, more difficult to make use of than others.

Educational Elements of Control Technology

As control technology systems began to be used in some schools, they were considered to consist of five educational elements:

1. Design and problem solving. This would involve selection of an appropriate project, collection of information, deciding how to go about constructing a solution and the actual design of this solution. This was an important first step.
2. Building the model to be machine controlled. The physical construction of the model – the engineering, comes next. This aspect of control technology is perhaps not as important with older students as with younger, but was still a part of the process.
3. Interfacing the model to the computer. While making the actual connections of the motors, lights, and sensors could be considered as part of the construction, this was better thought of as a distinct element involving different skills.
4. Use of sensors and feedback mechanisms. While not all models needed to include use of sensors, these sophisticated concepts were introduced in some secondary schools.
5. Programming. It is in control programming that computer science came in. Particularly at the senior school level, the writing of control programs was seen as the most important aspect of all, and as the culmination of the whole process.

Controlling a Robot: Control Programming

Controlling a robot is an essential aspect of robotics, and robots need to be programmed in order to perform their tasks. In principle, any programming language that can control the computer's input and output lines could be used to program a robot. At the robot-end, the programming consists of switching particular control lines on and off (to control robot motors), and checking whether other lines are registering a value or not (robot sensors). At the computer-end, a high-level programming language is used, which is translated into these on and off signals. In practice in the late 1980s and early 1990s, some programming languages proved more suitable for robot control than languages like Pascal or BASIC that were then used in many schools. FORTH and LOGO were useful in this context as were specialized robot programming languages such as VAL, WAVE, LM, SIGLA, and EMILY, although use of these specialized languages was not at all common in schools.

In the choice of which programming language to use, an early decision was first necessary on why the students were studying control technology. To what extent were they concerned just with controlling the device, compared to understanding how that control is achieved and delivered? If the answer was that they were more concerned with the problem-solving aspect and with controlling the device, but did not want to get involved in the actual bits and bytes, then LEGO Logo was undoubtedly the best programming language to adopt. At the other extreme, secondary school computer science courses that wanted to show the students something of interfacing, the use of a low-level programming language was found useful, but this was used only in a small number of cases.

Curriculum Possibilities Involving Use of Control Technology

Control Technology was one of the very earliest applications for microcomputers in education. At

the start of computer education in the late 1970s – long before the concept of LEGO Logo was born, a number of enthusiastic Australian teachers were interfacing their computers to all sorts of external devices. This tradition continued, and teachers with these interests continued to do incredible things with very little resources. Such activities were, however, not the norm.

Courses in control technology in some schools (particularly secondary and technical schools) were made up from many of the following elements:

- Problem solving and computing concepts
- Electronics – chips, analogue to digital conversion
- Interfacing – memory locations, data transfer
- Mechanics – motors, gears, and pneumatics
- Cybernetics – control systems
- Control programming – high and low-level
- Science – sensors, feedback, monitoring, and control
- Mathematics – design and geometry of robot arms
- History of mechanization and robotics
- English – robots in fiction
- Social science – robots and people
- Economics – the commercial imperative

Problem Solving and Computing Concepts

It is easy to see how computing concepts could be taught through a control technology course. Problem solving is essential and programming becomes very real when it causes a robot to move under your command! High level instructions could be written in Logo or another suitable control language and low-level instructions and monitor codes could also be investigated (Tatnall and Davey 1985, 1990).

Electronics and Interfacing

Control technology is based on the use of electronics, and while not many school wanted to dip into this some schools, particularly technical schools, did.

Science: Sensors, Feedback, Monitoring and Control

Robot control requires feedback of the exact whereabouts and condition of the robot's parts. Before a robot welder could begin welding, its controller needed to be sure that the tool was in the correct place and that the metal to be welded was also in place. Monitoring and control of science experiments was an important use of control technology, and students could make use of experimental apparatus equipped with sensors to take predesigned actions.

Mathematics: Geometry of the Robot Manipulator Arm

A good deal of mathematics is involved in the design of an industrial robot's manipulator arm. Like human limbs, robot arms are jointed. Unlike human joints, where only rotation is possible, two basic kinds of motion are possible at a robot arm joint: rotation and sliding. A jointed arm is characterized by its number of "degrees of freedom." In the simplest case, a machine has as many degrees of freedom as it has joints. Students at upper secondary and technical schools were encouraged to build models of Cartesian, polar, cylindrical, horizontally-jointed, vertically-jointed or anthropomorphic arms, and to study the mathematics involved in controlling each (Smith 1986).

English: Robots in Science Fiction

Robots in fiction are usually either very good or very bad; they are seldom just machines. A useful addition to the curriculum undertaken in some schools at all levels was to discuss this and to attempt to relate it to our conception of machines. The novel "Frankenstein," written by Shelly (1818), popularized the idea of a "non-human" monster. Although Frankenstein's monster was not a robot, the popular idea of a robot owes a lot to this novel. Many books and films have used robots in their plots and a good deal of interesting material can be found in the study of these. Apart from the classic "I Robot" and R. Daneel science

fiction series by Isaac Asimov (1950), there was Marvin the paranoid android in Douglas Adams' "Hitch Hiker's Guide to the Galaxy" (Adams 1979), as well as C3PO and R2D2 from Star Wars, and K9 and the Daleks from Dr. Who. Even junior primary school students had heard of, and wondered about, many of these robots.

Social Science: Robots and People

In the play "Rossum's Universal Robots" the author has Rossum say:

A man is something that feels happy, plays the piano, likes going for a walk, and, in fact, wants to do a whole lot of things that are really unnecessary ... But a working machine must not play the piano must not feel happy, must not do a whole lot of other things. Everything that doesn't contribute directly to the progress of work should be eliminated. (Čapek 1920)

This play was written about 70 years ago and paints a very pessimistic picture of robots and humans. Isaac Asimov, who did more to popularize the idea of robots, had a much more optimistic view, which he expressed in his many science fiction books.

Issues of the place of robotics in our society were seen as a fruitful study for senior secondary school students undertaking courses in Information Technology. There was plenty of material in the press, in books, and in magazines to support this study. The issue of what work robots *should* do had, even then, been under considerable debate for some time and to what extent they should be allowed to displace humans. This made a useful source of discussion and debate in secondary school English classes (Groves 1985).

Issues such as the problem of designing a guard-robot to patrol a factory at night in place of the night watchman were discussed. There were seen to be plenty of questions that students could research and discuss in this scenario. Questions such as: With what type of sensors would the robot be equipped? How would it move about? Should it be armed? What action should it take on discovering an intruder?

Economics

Industrial robots and control technology can be regarded as a replacement of the need to use human workers. While installing a robot does not necessarily mean sacking a worker, the industrial robot nevertheless acts the part of a worker. Most of the reasons industry needs to use robots are based on economics. Several Melbourne technical schools were linking control technology and economics in a novel manner. They were using CNC (Computer Numerically Controlled lathes) lathes to manufacture small items such as tow-balls for car trailers. Initially the teacher showed the students how to program the lathe to cut the tow-balls. Next the students were given the task of deciding on the price for which the tow-balls could be sold. This needed to take into account the cost of materials and the cost of using the lathe (based on construction time). The students then actually went into the business of selling the tow-balls. In the next stage, they tried to improve the efficiency of the process. Could the cutting program be improved so that the process could be performed more quickly, hence reducing lathe costs? Could it make more efficient use of the materials and so reduce waste?

Some Control Technology Projects

Any number of projects could be designed for year 11 and 12 students (Aged around 16–18) to build, particularly using Lego Technics, but some of those used in primary and secondary schools in Melbourne included:

1. **Maze solver.** Students at senior primary schools were asked to design a simple maze with one exit, and build it from cardboard or wood. Their LEGO robot vehicle would then need to be programmed to find its way out of the maze.
2. **Robot arm.** This was a more complex project used in some secondary schools and involved

students in building and testing a computer-controlled robot arm.

3. **Automated Conveyor Belt.** A less complex project involved building a conveyor belt that could automatically sort large Lego bricks from small bricks. Later this could be improved to sort light-colored bricks from dark-colored bricks.
4. **The robot “animal”.** In this quite complex project, students tried to build a robot vehicle that exhibited (pseudo) animal behavior such as shrieking when touched, grazing only on green grass (paper), avoiding hazardous materials, running away from bright lights, stopping when a shadow passed over it, stopping at the edge of a cliff, and patrolling its own territory.
5. **Mars explorer.** In another project, students were to design a robot to explore the Moon, Mars or another planet. It would need to be able to move around freely, to be well equipped with sensors, and to be able to transmit information from its sensors back to Earth.

Difficulties Found in Introducing Control Technology Courses

Times changed and new materials became available. By 1990, LEGO Technic materials had been readily available for several years, so why were they not being used in all schools?

There were several problems in the adoption of control technology materials in information technology courses. Firstly, there were, for many teachers, the difficulties of electric wires, power supplies, and connections to a computer, and many teachers stepped back in horror at the idea of all that this involved. Then there were the logistics of keeping track of all the small LEGO materials.

Next, there was the problem of the significant learning threshold (on the part of the students and the teacher) before anything useful could be done with control technology materials. Certainly, most people found that building the LEGO models was quite easy, but some teachers found that also having to learn to write control programs was a bit daunting. While these materials were not really

very difficult to use, there was a perception among busy teachers that their use would involve a lot of preparation work. The task of designing such curricula at the school level was a time consuming one, and one more impediment to the widespread use of control technology. The problem of cost was also not insignificant, as the purchase of the LEGO materials, suitable interfaces, software, and computers involved quite a lot of money. For many schools, particularly primary schools, obtaining sufficient funds to buy enough of these materials for class use was very difficult.

Conclusion

The term *robot* has always held some fascination with school students, particularly after seeing the humanoid variety in many science fiction films and comics. The thought of being able to construct your own robot (or some aspects of it) was instantly appealing in the 1980s (and also today). Despite the implementation difficulties involved, the educational benefits of including Control Technology units in Information Technology school subjects began to become clear to see in the late 1980s, although not all schools took advantage of this. Students though thought it fun and were enthusiastic about its use. Teachers were then beginning to realize that such technology related well to the outside world, was a good vehicle for practice in problem solving, and was worth learning about.

Cross-References

- ▶ [Beginnings of Computing in School Education in Australia](#)
- ▶ [Technological Innovation in ICT for Education](#)

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Copyright

- [Creative Commons](#)

Co-regulation

- [Shared Regulatory Planning in Minecraft](#)

Correspondent Learning

- [Open Educational Resources and Distance Learning, Challenges and the Way Forward in Higher Education](#)

Course Management Systems

- [Learning Management Systems, An Overview](#)

Creative Commons

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Synonyms

[Copyright](#); [FOSS](#); [Free/open source](#); [Intellectual property](#); [Open source](#); [Public domain](#); [Some rights reserved](#)

Creative Commons

While it might sound encouraging to believe that “information wants to be free,” this mantra often represents a misguided belief that intellectual property rights have no place in modern society. In fact, this is actually quite far from what Stuart Brand likely meant when he purportedly said this to Steve Wozniak in 1984. What Brand probably meant was that technological constraints placed on information (text, images, code, audio, video, etc.) are by default arbitrary add-ons put in place after the fact – after the initial creation of the item in question – and are therefore arbitrary and typically counterproductive to the widespread diffusion and use of these items. That is, the default state of information is free in terms of

accessibility. Locking it down by way of digital rights management (DRM) systems and platforms to protect the intellectual property rights of the respective creator(s) always requires additional measures to do so. While anthropomorphizing information as having distinct “wants” of course does not make any literal sense, since information itself cannot “want” anything, the initial, default state of all information is free until otherwise changed.

Richard Stallman, founder of the Free Software Foundation and the GNU General Public License, would later add to this idea by making the distinction one between “free” and “freedom”, respectively. Lessig himself attempts to qualify this difference when he stated that “‘Free’ has different senses, only one of which refers to ‘price’.” Lessig further adds that “A much more fundamental sense of ‘free’ is the ‘free’... in the term ‘free speech’ or perhaps better in the term ‘free labor’. Not free as in costless, but free as in limited in its control by others” (Stallman 2002).

Stallman believes that “generally useful” information should be available for adoption and/or adaptation as needed. He does not attempt to stipulate a definition to frame exactly what he means by “generally useful,” so the term itself is subject to wide interpretation. That being said, after the initial creation of such “generally useful” information takes place, what then should be done with it to disseminate and/or otherwise promote it to the world or some narrow slice thereof? This is what Lessig, Abelson, Eldred, and Plotkin attempt to address with their collaborative brainchild, Creative Commons.

As the name implies, Creative Commons represents a middle ground in the intellectual property ecosystem – a step somewhere between public domain (no rights reserved) and copyright (all rights reserved). Lessig and the other co-founders based Creative Commons around a series of licenses creators can choose for content they create. The licenses are written in both legally binding and plain English text, to serve both content producers and content consumers.

These licenses can be easily applied to any content by way of simple, online forms, and the licenses can be customized as needed by the

content producers. The end result is a middle ground between the public domain and copyright, designed so creators can metaphorically “free” their creative works for greater diffusion into society, for the common good.

This middle ground is not a static, “one size fits all” approach but is instead a sliding scale, allowing more or less control based on the desires of the individual content producer, in order to help “clarify the rules of creativity” (Reticulum Rex 2003). These licenses ultimately provide content producers with a means to “...retain copyright while allowing others to copy, distribute, and make some uses of their work” at the discretion of the content producer. Additionally, every Creative Commons license ensures the following:

1. The content producers in question (referred to as “licensors” in Creative Commons documentation) get the credit for their work they deserve.
2. The licenses are applicable and enforceable worldwide, “...because they are built on copyright” (Creative Commons, About the Licenses).

This theme of “enforceable credit” is a central tenant to all of their licenses. The primary Creative Commons licenses are as follows, with some offshoots and variations made in the past decade (About the Licenses 2017):

- **Attribution** (CC BY) – This license allows distributing and/or modifying work, as long as credit is given to the original content producer.
- **Attribution-ShareAlike** (CC BY-SA) – This license allows distributing and modifying work, as long as credit is given to the original content producer. The new, modified work must be licensed the same way.
- **Attribution-NoDerivs** (CC BY-ND) – This license allows distributing the work unchanged, commercially or noncommercially, as long as credit is given to the original content producer.
- **Attribution-NonCommercial** (CC BY-NC) – This license allows distributing and modifying work noncommercially, as long as credit is given to the original content producer. The

new, modified work does *not* need to be licensed the same way.

- **Attribution-NonCommercial-ShareAlike** (CC BY-NC-SA) – This license allows distributing and modifying work noncommercially, as long as credit is given to the original content producer. The new, modified work *must* be licensed the same way.
- **Attribution-NonCommercial-NoDerivs** (CC BY-NC-ND) – This license allows distributing work unchanged, noncommercially only, as long as credit is given to the original content producer.

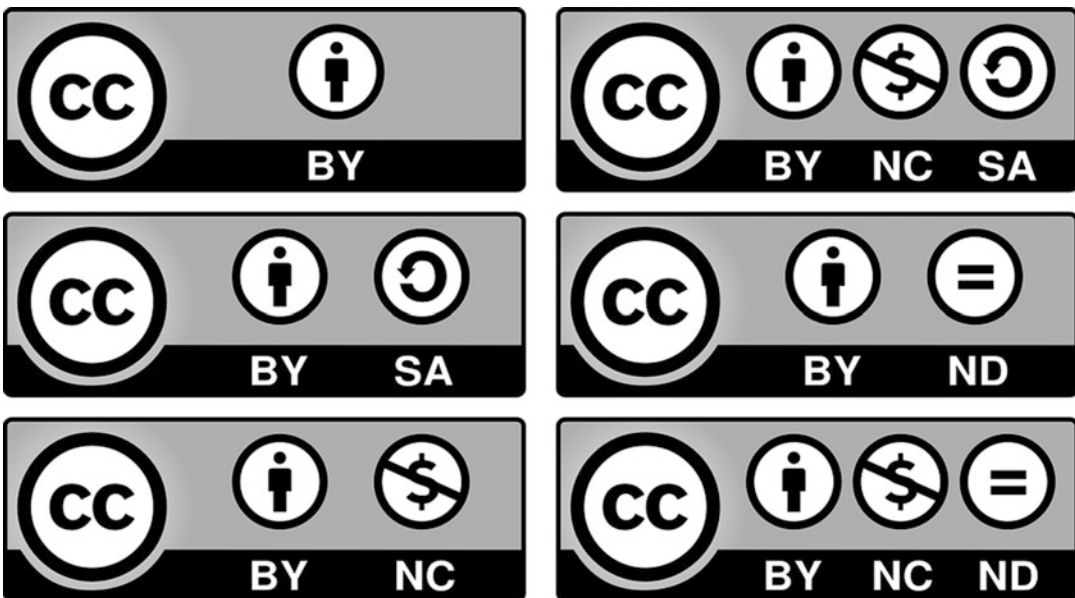
Each license has its own icon associated it with that links to additional legal and machine-readable information as in Fig. 1.

In many respects, the Creative Commons licenses represent a metaphorical extension of the GNU General Public License and the notion of “copyleft”, developed by Stallman several years prior. Stallman’s goal with the GNU General Public License was also to have a middle ground between the public domain and copyright, yet for different reasons. His intention was to make absolutely certain that programmers who wished to release their code for free could ensure that it

remained so permanently. If their code was only made available in the public domain, anyone could freely use it and modify it as needed, but they could also modify it and then copyright it – effectively forking it, thereby closing it off from further modifications and free use. “If middlemen could strip off the freedom,” Stallman argues, “we might have many users, but those users would not have freedom” (Stallman 2002).

The method of “copylefting” a program involves stating that the code in question is copyrighted, then “. . . we add distribution terms, which are a legal instrument that gives everyone the right to use, modify, and redistribute the program’s code or any program derived from it but only if the distribution terms are unchanged.” Taking this approach, Stallman asserts, makes “the code and freedoms . . . legally inseparable” (Stallman 2002). The GNU General Public License most closely matches the Creative Commons Attribution-NonCommercial-ShareAlike license, though there are still several minor differences.

Depending on the context and specific needs of the respective content producer(s), any of these licenses – of course including the GNU General Public License – may be relevant. If



Creative Commons, Fig. 1 Creative Commons licenses. (Note: image free for commercial use; no attribution required)

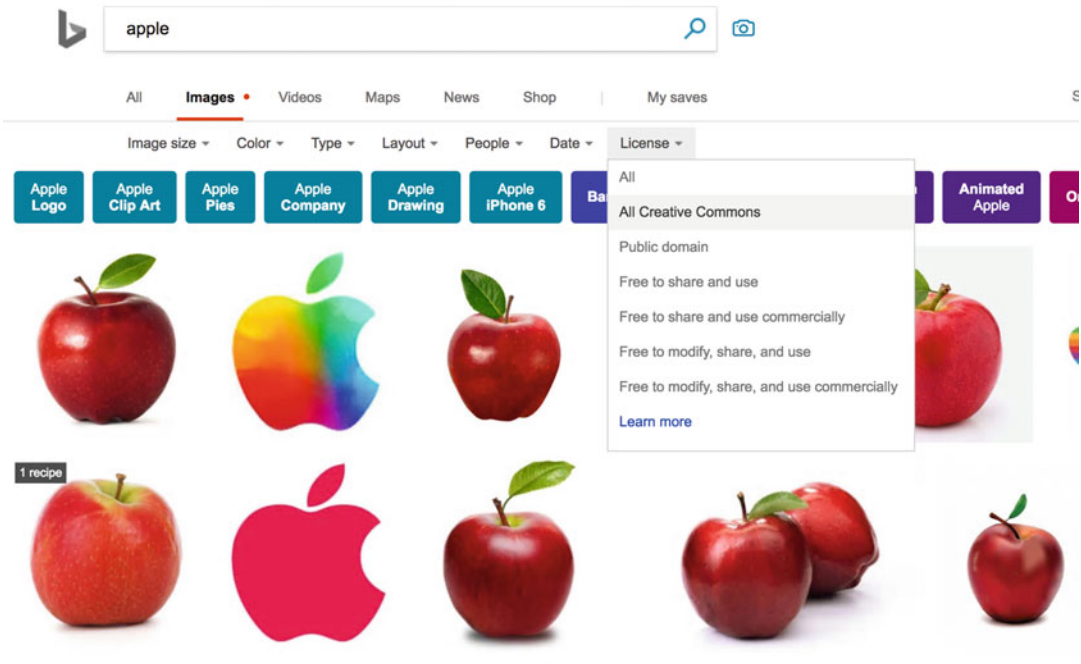
photographers want to make collections of their images available royalty-free, for example, they could choose to do so under an “attribution-only” Creative Commons license, which requires users to essentially give creative credit where such credit is due. These same photographers could also release their work under an “attribution-only/noncommercial” license, which would still make such content available royalty-free, but only for personal, noncommercial use.

The ties between Creative Commons and social media are simultaneously obvious and tenuous. While not specifically targeted at growing any individual social media platform or services, Creative Commons-licensed works have no doubt played a role in a broader sense of the term. A central premise of Creative Commons is that, historically, creativity has always been built upon the past work of others and that the “full potential of the Internet” can best be realized by unleashing the full potential of creative works as content producers see fit to share them (Building on the Past 2003). As of this writing, Creative Commons now claims over 1.2 billion licensed

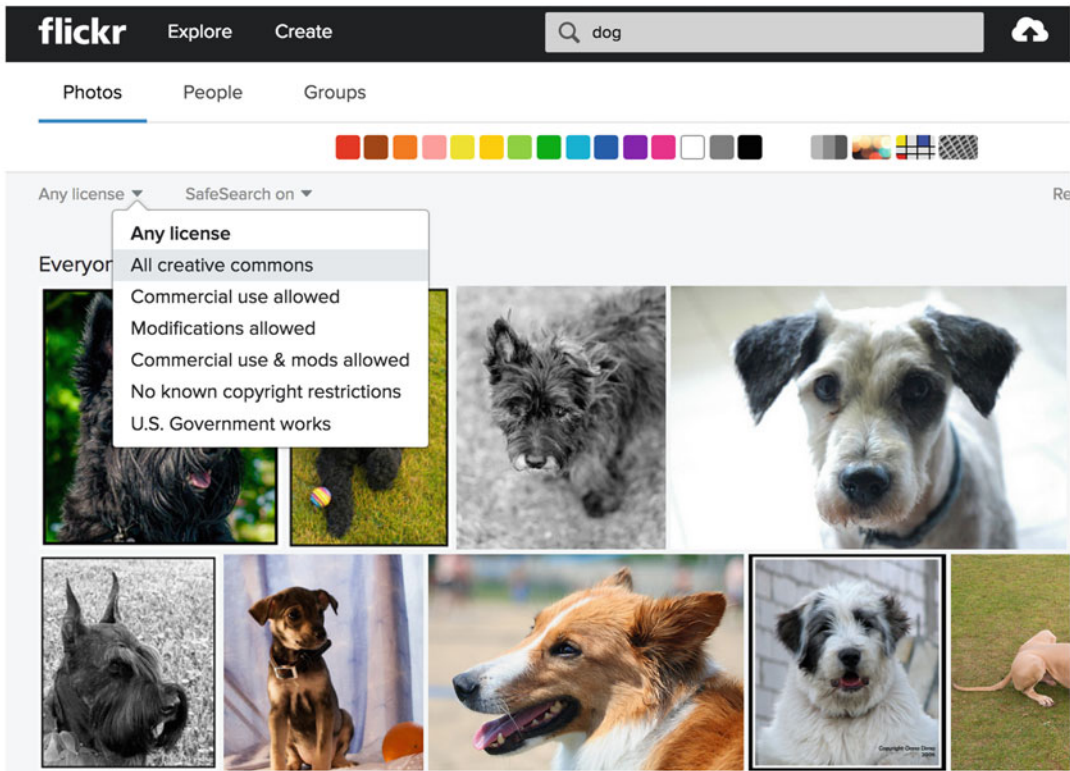
works in various formats (State of the Commons 2017), to “. . . help authors and artists build a body of free culture they can draw from in return.” This represents a sizable growth trajectory given that it started with roughly 100,000 licensed works in 2001 (Reticulum Rex 2003).

So, while Creative Commons cannot be directly tied to the growth of Facebook, Instagram, Twitter, Tumblr, SoundCloud, Flipboard, and other social media platforms, Creative Commons has still perhaps indirectly aided in their broader use. If anything, Creative Commons itself can perhaps be seen as a separate, parallel social media platform that can overlap with any of the platforms listed above. There is certainly no shortage of examples of Creative Commons-licensed images available on Instagram or Flickr, for example, as well as Creative Commons-licensed audio files on SoundCloud. Searching for Creative Commons-licensed content is equally easy in these and other platforms (Fig. 2).

The impact of Creative Commons has had and continues to have on these platforms is perhaps



Creative Commons, Fig. 2 Creative Commons search tools using Bing



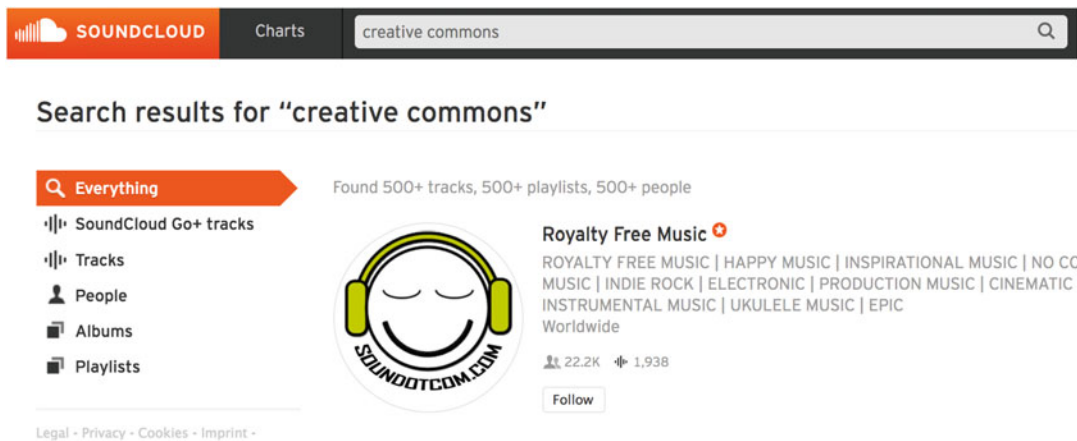
Creative Commons, Fig. 3 Creative Commons image search, Flickr

less relevant than the broader use and acceptance of Creative Commons, in general. In terms of the relationship to Creative Commons, these social media platforms really just represent a series of delivery methods content producers can use to deliver and disseminate their works to others. They are not the end game unto themselves toward this end but rather a means to an end to further the act of sharing and creativity (Figs. 3 and 4).

The same could be said in industries where Creative Commons might initially seem antithetical, such as academic publishing. The open-access movement for academic publishing, for example, might never have become as widely diffused and accepted as it is now without the ability for authors to use Creative Commons licenses. The Science Commons project of Creative Commons has served as a key player in helping foster and promote Open Educational Resources (OER) worldwide. Similar initiatives,

including the Berklee Shares project, MIT Open Courseware, and a host of other efforts, would likely not even exist without Lessig and others initially having paved the way with Creative Commons (Berklee Shares 2017).

Many academic publishers now include options for authors to release their works under Creative Commons licenses. Elsevier, for example, offers authors "...a choice between a commercial and a noncommercial Creative Commons license for gold open access articles" in numerous journals (Elsevier Open Access Licenses 2017). The specific licenses used are the Attribution 4.0 (abbreviated as the CC BY) and the Attribution-Noncommercial-No Derivatives (abbreviated as the CC BY-NC-ND) (User Licenses Offered by Elsevier 2017). Given the size and stature Elsevier commands in academic publishing, this represents a huge new avenue for authors who want their works to become as broadly disseminated as possible.



Creative Commons, Fig. 4 Creative Commons audio search, SoundCloud

Louis Suarez-Potts, longtime open source advocate and former community manager of the OpenOffice projects, agrees. When discussing open source initiatives and related alternatives to traditional copyright at the University of Buffalo, he argued that such efforts work “. . . regardless of the motivator; and motivators beyond price work even in closed source environments. What counts, then, is engaging people so that the value of their actions and role goes beyond price” (Lim 2009). Kembrew McCleod echoes this sentiment. He asserts in his increasingly relevant text, *Freedom of Expression*, “the ability to record, comment on, and distribute media content is essential for the survival of a robust democracy and the cultivation of a free culture in the information age” (McCleod 2007). While McCleod primarily meant this in reference to traditional notions of fair use, his views still echo the importance of what the Creative Commons initiative has been all about and what works have been developed as a direct result of this effort.

Information may not want to be free, but content producers may want the option of making it so. Even high-profile skeptics of alternative copyright solutions like Bill Gates, who once famously derided those promoting such efforts as being “. . . new, modern-day sort of communists” (Andrews 2005), have come around. The Bill & Melinda Gates Foundation now *mandates* that all funded research projects be published under the Creative Commons Attribution 4.0

generic license or equivalent. The foundation leadership took this once unthinkable step to promote “. . . The free, immediate, and unrestricted access to research will accelerate innovation, helping to reduce global inequity and empower the world’s poorest people to transform their own lives” (Gates Foundation, Open Access Policy).

There are 1.2 billion reasons why Creative Commons works and how this effort has helped disseminate knowledge and creative works worldwide. Let us hope there will soon be 1.2 billion more reasons in the coming years.

Cross-References

- [Collaboration and Social Networking](#)
- [Digital Citizenship, A Sociocultural Snapshot](#)
- [Distance Learning](#)
- [Educational Resources, Hypermedia](#)
- [Pedagogical Possibilities for the History of Computing](#)
- [Why Teach History of Computing?](#)

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Creativity

- [Digital Literacy, Creativity, and Autonomous Learning](#)

Cross-cultural Collaborations

- [Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India](#)

Culture

- [Bunyip, The Australian Educational Computer that Was Never Built](#)
- [Digital Citizenship, A Sociocultural Snapshot](#)
- [Innate Abilities and Learning in Higher Education](#)

Curricula in Computer Science

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Introduction

In recent years, a number of reports from various countries have expressed concerns about Computer Science being neglected and school curricula not serving learners' or their countries' needs well (Joint Informatics Europe and ACM Europe Working Group on Informatics Education 2013; The Royal Society 2012; Wilson et al. 2010). Subsequently many countries have reviewed their curricula and in some cases brought in major reforms that focus on incorporating more Computer Science (Webb et al. 2017). This article aims to review concerns and recent changes and to examine their rationale. Furthermore, the article discusses the challenges associated with achieving a curriculum, incorporating Computer Science, that is fit for purpose. First key terminology in relation to Computer Science curricula is defined since variations in the use of terminology can be a source of confusion.

Terminology and Definitions

When discussing curricula for Computer Science, the need to identify an acceptable working definition for Computer Science as a curriculum subject is a key consideration. Some popular definitions (Fluck et al. 2016) are:

1. It seeks to answer the following questions: What is information? What is computation? How does computation expand what we know? How does computation limit what we can know (Denning 2007)?
2. The study of computers and algorithmic processes, including their principles, their hardware and software designs, their implementation, and their impact on society (ACM 2003).

3. The scientific and practical approach to computation and its applications and the systematic study of the feasibility, structure, expression, and mechanization of the methodical procedures (or algorithms) that underlie the acquisition, representation, processing, storage, and communication of and access to information (https://en.wikipedia.org/wiki/Computer_science).

In addition, definitions based on areas of knowledge can be found through widely adopted curricula, such as the ACM/IEEE Computer Science curriculum for undergraduates (Sahami et al. 2013). The *Wikipedia* definition (https://en.wikipedia.org/wiki/Computer_science) gives a clear overview and reflects recent consensus on the general nature of Computer Science as well as current practice, so the *Wikipedia* definition will be used throughout this article.

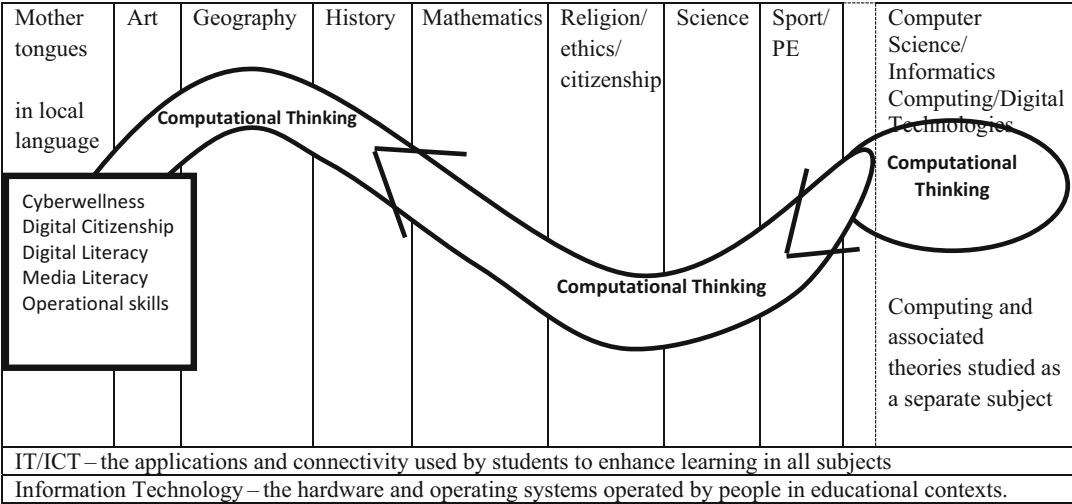
This article uses the term, Computer Science, for the curriculum subject, and this is in line with a number of countries and organizations, including the influential US-based “Computer Science Teachers Association” that has developed a set of standards for Computers Science (<https://www.csteachers.org/page/standards>). However, the name used for the curriculum subject varies across different countries. For example, Informatics is slightly broader than Computer Science but is the term used widely across Europe to refer to this discipline. For example, the Joint Informatics Europe and ACM Europe Working Group on Informatics Education use the term Informatics to “cover the entire set of scientific concepts that make information technology possible” (Joint Informatics Europe and ACM Europe Working Group on Informatics Education 2013, p. 9).

Another key term that is central to many recent curricula for Computer Science is Computational Thinking, an approach to problem-solving conceived by Seymour Papert (1996) and recently re-emphasized by Jeannette Wing (2006). Overall, Computational Thinking is about analyzing and solving problems and presenting solutions in such a way that they can be

implemented on computers. Therefore, Computational Thinking draws on fundamental concepts and techniques from Computer Science such as abstraction, decomposition, pattern recognition, and algorithm design. Computational Thinking, according to Wing, may be regarded as a fundamental skill set, for the digital age, alongside literacy and numeracy; therefore the position of Computational Thinking in the curriculum has become the subject of some debate. The diagram in Fig. 1, based on (Webb et al.), shows Computational Thinking, developed in Computer Science but snaking across the curriculum, where students use Computational Thinking processes or elements of Computational Thinking to support their learning of other subjects as well as to develop their experience of the ubiquity and importance of Computational Thinking.

Concerns About Computer Science in the Curriculum

The focus of the major reports that highlighted concerns about Computer Science (Joint Informatics Europe and ACM Europe Working Group on Informatics Education 2013; The Royal Society 2012; Wilson et al. 2010) was that the academic curriculum subject, Computer Science, had been lost from school curricula as a result of a too limited focus on developing only basic digital literacy. Basic digital literacy is important as it can enable students to use business applications, such as databases and spreadsheets, as well as understand and use Internet-based resources ethically and safely. However, typically digital literacy does not provide students with the understanding together with technical and creative skills to enable them to innovate with technology and thus contribute to the development of economies and society. Therefore, all of the reports (Joint Informatics Europe and ACM Europe Working Group on Informatics Education 2013; The Royal Society 2012; Wilson et al. 2010) advocated the need for both digital



Curricula in Computer Science, Fig. 1 Computing-related terms in relation to the conventional school curriculum

literacy and Computer Science in school curricula. Subsequently, in many countries, new curricula have been developed that incorporate Computer Science (Webb et al. 2017), typically throughout compulsory education (see, e.g., <https://www.csteachers.org/page/standards>; <https://www.australiancurriculum.edu.au/f-10-curriculum/technologies/>; Department for Education 2013; Ministry of Education New Zealand 2017).

Defining the Scope of a Curriculum

An analysis of developments in five countries as well as a review and content analysis of curriculum reports (Webb et al. 2017) suggested key issues to consider when designing Computer Science curricula. First there is a consensus (see Table 1) across curriculum reports about the key concepts and techniques of the discipline (Webb et al. 2017). However, there is as yet no consensus about the importance of more general intellectual practices such as persistence in working through problems and tolerance for ambiguity as well as the importance of collaborative learning and social competence developed

through group work that were emphasized by the European report (Joint Informatics Europe and ACM Europe Working Group on Informatics Education 2013).

Thus, the recent curriculum design, incorporating Computer Science, has achieved the goal of defining “powerful knowledge,” i.e., specialized discipline-based knowledge, which is an entitlement for learners (Young 2013). As Young (2013) argued, “powerful knowledge,” although constantly changing, can be determined by subject experts, and this is typically how the content of these curricula has been specified. A challenge remains to ensure the currency of curricula. For example, in defining curricula for undergraduates, a key challenge discussed by the ACM/IEEE was to maintain the curriculum within an acceptable size given the rapid developments in the field, so the focus is on identifying new topics that merit incorporation and continuing to evaluate the importance of existing topics (Sahami et al. 2013). For secondary schools, it is also important to maintain the currency of the curriculum, in order both to provide a sound basis for future study and to promote students’ motivation by enabling them to understand the relevance of what they are studying. As shown in Table 1,

Curricula in Computer Science, Table 1 Analysis of key areas of knowledge of Computer Science in curriculum reports. (Adapted from Webb et al. 2017, p. 459)

	Computer Science Teachers Association (CSTA) curriculum standards (http://www.csteachers.org/page/standards)	Royal Society report (The Royal Society 2012)	Joint Informatics Europe and ACM Europe Working Group (Joint Informatics Europe and ACM Europe Working Group on Informatics Education 2013)
Overview of “discipline” of Computer Science/ Informatics and foundational principles	The study of computers and algorithmic processes, including their principles, their hardware and software designs, their implementation, and their impact on society (ACM 2003)	Encompasses foundational principles, widely applicable ideas and concepts, as well as techniques and methods for solving problems and advancing knowledge as well as a distinct way of thinking and working (page 19)	Informatics is a distinct science, characterized by its own concepts, methods, body of knowledge, and open issues (page 3).
Key areas of conceptual knowledge	Strands are data and analysis, algorithms and programming, impacts of computing, computing systems, networks and the Internet computational thinking, collaboration, computing practice, computers and communication devices, and community, global, and ethical impacts	Programs, algorithms, data structures, architecture, and communication	Provides the following as examples from a long list of concepts: algorithm, performance and complexity, data structure, concurrency (parallelism) and distribution, language (including programming languages), abstraction
Techniques and methods	A wide range including techniques and methods for analyzing massive data, solving problems, authentication, recursion, object-oriented modelling, search, testing, and refinement	Computer Science “methods” or ways of thinking include: • Modelling: representing chosen aspects of a real-world situation in a computer • Decomposing problems into sub-problems and decomposing data into its components • Generalizing particular cases of algorithm or data into a more general-purpose, reusable version • Designing, writing, testing, explaining, and debugging programs (page 20)	Problem-solving techniques include: • Representing information through abstractions • Logically structuring and analyzing data • Automating solutions through algorithmic thinking • Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient solution • Formulating problems in a way that facilitates the use of a computer • Generalizing (page 12/13)
Ways of thinking and working	Practices include communicating, testing, abstraction, creating, solving computational problems, collaborating	Computational thinking Logical thinking Systematic thinking Analytical thinking	Intellectual practices include: • Confidence in dealing with complexity • Persistence in working with difficult problems • Tolerance for ambiguity • Ability to deal with open-ended problems • Ability to deal with a mix of both human and technical aspects • Ability to communicate and work with others to achieve a common goal or solution (page 13)

there is currently a consensus over key areas of conceptual knowledge, but at a more detailed level, there can be a long list of concepts (Joint Informatics Europe and ACM Europe Working Group on Informatics Education 2013). Furthermore, even some of the standard curriculum content may be brought into question by future curriculum content based on new technological developments, for example, quantum computers that operate on completely different principles (Fluck et al. 2016). In summary, there is consensus regarding key concepts and techniques crucial for Computer Science in the school curriculum. However, the structure of the curriculum and the appropriate age for introduction remain challenging as discussed next.

Structure of the Curriculum

Ideally the structure of a curriculum would be determined by detailed evidence of learners' progression in understanding. For example, in some subjects such as mathematics, detailed "trajectories" of learning have been determined (Sztajn et al. 2012). Such trajectories represent ordered expected tendencies determined through empirical research designed to identify highly probable steps students follow as they develop their initial mathematical ideas into formal concepts, recognizing that each student's path can be unique. However, the limited empirical evidence for learners' trajectories in the development of understanding and skills in Computer Science, together with relatively limited understanding of pedagogy compared with other disciplines, presents challenges for specifying structure and organization of the curriculum. Curricula design may be guided by epistemological considerations and other constraints (Young 2013; Winch 2013) and later informed by empirical evidence. Typically, therefore, the current structure of curricula is defined by "best guesses" by subject experts and experienced teachers. A promising approach that is exemplified by the recently redesigned curriculum for Poland (Webb et al. 2017) uses a spiral structure where three key elements are

incorporated at each level, but their emphasis and the examples used change as the students progress through the years. In the Polish curriculum, the three key elements are:

1. Problem situations, cooperative games, and puzzles that use concrete meaningful objects – discovering concepts
2. Computational thinking about the objects and concepts – algorithms and solutions
3. Programming

The basic idea of a spiral curriculum is well-known in curriculum design and was proposed originally by Bruner (1960). A major advantage of the spiral structure is that students revisit key concepts regularly but with different examples. The idea of revisiting key concepts but with increasing complexity works well for a Computer Science curriculum where clearly the three elements identified above can be tackled at different levels of complexity. This revisiting of key ideas is useful for developing deep understanding of complex concepts and probably particularly critical for learning programming, which is known to be difficult and to require much practice (Robins et al. 2003). There is still a need for detailed empirical research to gain a better understanding of learning trajectories, but some progress has been made in relation to programming constructs (see, e.g., Rich et al. 2018).

A consensus regarding the best starting age for Computer Science being young, about 5–7 years old, emerged from a comparison of curriculum development considerations in Poland, the UK, and Australia (Webb et al. 2017). The availability of programming environments and other software designed to enable younger learners to learn programming also supports this early development of Computer Science learning (Duncan et al. 2015). Arguments for starting Computer Science at an early age include (1) learning programming is difficult, but a consensus is emerging that learning some of the techniques, approaches, and thinking involved in programming at a younger age enables more students to become successful in programming and (2) developing student

self-efficacy in programming and Computer Science at an earlier age may reduce the gender gap (Duncan et al. 2015; Webb et al. 2017).

Summary and Conclusion

In summary, concerns in recent years over the loss of Computer Science from the school curriculum have led to the redevelopment of curricula in many countries. These development processes, typically led by subject experts and experienced educators, have shown a consensus regarding key conceptual areas and important techniques in the academic discipline of Computer Science. Although there is as yet insufficient detailed evidence of students' learning trajectories to be confident of how progression should be structured into curricula, using a basic spiral curriculum structure is a promising approach that enables key concepts to be regularly revisited at increasing levels of complexity. Ongoing research is needed to develop and test learning trajectories for knowledge and skills in Computer Science across all school-aged learners.

Cross-References

- [Computational Thinking](#)
- [Computing Curricular Report CE2016, A Summary](#)
- [Computing Curricular Report IT2017, A Summary](#)
- [Learning Programming, Success Factors](#)
- [Teaching about Computing](#)
- [Teaching with Computing, Educational Games](#)
- [Value of Teaching Computer Science](#)

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Curriculum for Making

► [Makerspaces](#)

Cyberlearning

► [Institutional Repositories Versus Learning Object Repositories, Challenges and the Way Forward for Higher Educational Institutions](#)

D

Data Analysis

- [Data Mining for Educational Management](#)

Data Analytics

- [Data Mining for Educational Management](#)

Data Driven Decision Making

- [Decision Support Systems and Knowledge Management in Education](#)

Data Literacy

- [Data Science Education](#)

Data Mining for Educational Management

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Synonyms

[Data analysis](#); [Data analytics](#); [Knowledge discovery](#); [Patterns discovery](#)

Definition

Based on computer information systems, data mining (DM) is a technique designed to scan huge data repositories, generate information, and discover knowledge (Vlahos et al. 2004). By applying different tools, DM seeks hidden relationships in raw data in order to discover data patterns. Therefore, DM can play an important role in unveiling a broad set of findings and, consequently, offers valuable support in decision-

making. The incorporation of DM into the educational arena has given rise to a new research field called educational data mining (EDM) (Anjewierden et al. 2011). In this case, the aim is to design models, tasks, methods, and algorithms for exploring data from educational settings (Peña-Ayala 2014). Altogether, they can help to improve management activities in educational institutions, thus empowering the performance of educational managers.

Introduction

Many evidences support the statement that knowledge is among the main assets of organizations (Nonaka et al. 2008). Part of the organizational knowledge resides in the minds of employees, as intrinsic knowledge, and another part is stored as data in companies' repositories. In both cases, they consist of hidden knowledge, and, as with any other resource, the organizations cannot afford to misuse it. This way, as the knowledge management approach has proven to be an effective means of gathering the intrinsic knowledge of the organization's personnel and convert it into explicit knowledge, it is also important to explore the hidden knowledge in an organization's data and transform it into explicit knowledge. All these efforts can greatly contribute toward improving the decision-making process. DM arises as a powerful approach to aid in the accomplishment of this goal. Consequently, it is worth managers being knowledgeable about this technique.

Data Mining

The starting point of a DM approach is the availability of data repositories. The development and ubiquitous use of information technology have led to all kinds of organizations, almost inadvertently, disposing of datasets resulting from their core activities. Information about customers, personnel, transactions, etc. is stored in electronic records. In some cases, repositories are comprised of heterogeneous datasets; sometimes their size is so huge that it makes it difficult to extract useful

and comprehensive knowledge from them. Thus, the raw material – the data – can be assimilated into a “mine” with potential treasures within. The challenge is to develop and apply the appropriate tools needed “to extract” the hidden wealth as useful and comprehensible knowledge. In turn, this knowledge constitutes the basis for improved decision-making. The main difference with statistical analysis lies in the fact that DM involves methods that search for new and generalizable relationships and findings, rather than attempting to test prior hypotheses. This difference in the approach followed is the reason why data mining is also referred to as “knowledge discovery” in databases (Collins et al. 2004).

DM technique originated within this context, with the aim of discovering hidden and nontrivial relationships in information, of various types, extracted from large amounts of data (Campagni et al. 2015). Many areas have benefited from adapting the DM technique to solve their problems – among them, finance, healthcare systems, marketing, stock markets, telecommunication, manufacturing, and customer relations. In fact, it can be recognized as a contemporary tool for building knowledge management systems (Jashapara 2011). DM is a broad concept grounded on a set of disciplines, such as statistics, artificial intelligence, and computer science. Different subsets contribute to the development of DM – among them, probability, machine learning, natural language, neural networks, database management systems, etc.

The literature offers a broad set of experiences, demonstrating that statistical methods are well-established tools for analyzing data and extracting useful information. However, DM emerges as a fresh approach to understanding hidden patterns and data prediction. A reason explaining why DM has turned out to be very popular among researchers lies in the many standalone or desktop data mining tools available on the market. The following can be cited as examples: Microsoft Excel, SPSS, Weka, Protégé as Knowledge Acquisition System, and Rapid Miner. Some of them (e.g., MS Excel Mining tool) are normally available to instructors and educational managers, and they can benefit greatly from the existing knowledge of Excel.

The development of the DM technique usually follows one of two main approaches. The descriptive approach focuses on producing patterns that explain or generalize the intrinsic structure, relations, and interconnections of available data (Peng et al. 2008). The predictive approach centers on estimating unknown or future values of dependent variables based on the values of related independent variables (Hand et al. 2001). To follow either of these approaches, a number of methods and techniques can be adopted. A sample of them includes Markov models, Bayes theorem, decision trees, linear regression, frequencies, and hierarchical clustering.

Educational Data Mining

The International Educational Data Mining Society (2018) defines educational data mining (EDM) as an “emerging discipline, concerned with developing methods for exploring the unique and increasingly large-scale data that comes from educational settings and using those methods to better understand students and the settings which they learn in.” Thus, EDM is a relatively recent research area that explores and analyzes the information stored in student and institutional databases in order to understand and improve the performance both of the student learning process and of educational institutions. Data is analyzed by using statistical and algorithms with the aim of resolving problems of an educational nature and improving the entire educational

process. EDM is a growing research area that involves researchers from all over the world from both different and related areas (Campagni et al. 2015).

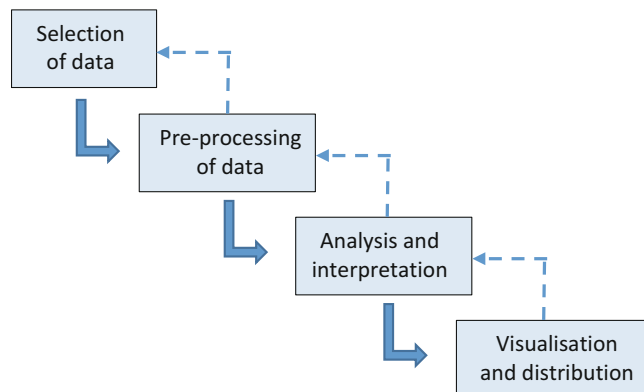
According to Peña-Ayala (2014), close to 98% of the published works about EDM have appeared since 2000. EDM has shifted from isolated papers published in conferences and journals to dedicated workshops, an annual international conference on educational data mining (<http://www.educationaldatamining.org>), a specialized journal on EDM (*Journal of Educational Data Mining*), as well as books and handbooks. Although focused on a specific scope, the educational setting, EDM shares with other disciplines its basic principles. Therefore, most of the processes that format and refine data, as well as the tools adopted to handle the datasets, are the same that can be found in other instances where the DM technique is applied.

Process and Tools in EDM

Slater et al. (2017) proposed a set of guidelines to facilitate the work of educational researchers and practitioners when using the DM technique. The following paragraphs summarize the suggested steps and tools that can potentially be adopted (Fig. 1).

The data used during the EDM process should respond to the objective of the research; thus, the correct adoption of the data source is of great importance, especially in environments with different databases which can misdirect the focus of

Data Mining for Educational Management,
Fig. 1 Steps in data mining



the researcher. In educational settings, data is stored in repositories that might appear in forms and formats that do not enable them to be analyzed directly. Often, educational researchers and practitioners work with data recorded in forms that are not immediately amenable to analysis, as could be the case with data retrieved from log files or learning management systems (LMS). Some characteristics of these types of educational data mean that it may be defined as messy; sometimes incomplete; fragmented in several parts that must be merged; and occasionally unfamiliar, inconvenient, or in highly unusual formats. Before performing an analysis, the data should offer a meaningful format. In addition, data needs to be cleaned and cases and values that are not simply outliers, but clearly incorrect, removed (i.e., cases where birth dates have impossible values). An example of tools well suited for the manipulation, cleaning, and formatting of data are Microsoft Excel, Google Sheets, and the EDM Workbench.

The next step after data adaptation to a workable format is the analysis and modelling of the dataset and the validation of the resulting models. There is a full range of DM algorithms. According to the objectives pursued, a certain algorithm is to be adopted. The knowledge of the data miner is crucial for choosing the correct approach. Furthermore, a high degree of knowledge of application domains is required to interpret results and evaluate whether further exploration is needed. Additionally, data expertise is required to explain strange patterns that may be due to data pollution or other causes, such as data conversions. Therefore, the analysis step may be subject to a number of uncertainties, and, consequently, the data miner is advised to follow a holistic approach. A set of tools that are appropriate for this task include RapidMiner, Waikato Environment for Knowledge Analysis (WEKA), KEEL, KoNstanz Information MinEr (KNIME), Orange, and SPSS.

A final step, once the analysis has been conducted and the results validated, is that of disseminating the output in legible and informative visualizations. Occasionally, good visualization schemes are crucial for deriving meaning

from data. Therefore, the adoption of appropriate tools and methods for visual analytics can effectively support academics and practitioners in gaining knowledge and insight from data, as well as communicating its implications. Although many of the aforementioned tools are accrued with graphical data displays, researchers and practitioners can make use of a set of tools designed to create polished and informative graphs, charts, models, networks, diagrams, and other forms of visualized information. Examples of this kind of tool are Tableau, D3.js, and InfoVis. A final consideration for researchers and practitioners of EDM, as pointed out by Slater et al. (2017), is that no *one* tool is ideally suited to conducting the entire process of analyzing datasets from start to finish. As different tools are uniquely suited to different tasks, they must be carefully chosen in order to take advantage of their potential.

Limitations of EDM

Most data mining techniques work best with very large samples. In this regard, Andonie (2010) pointed out that some data mining tools, such as neural networks, may not be able to accomplish the goal of understanding hidden patterns, since small datasets cannot provide enough data to fill the gaps. Several authors concluded that small datasets limit the scope of the DM technique (Yuan and Fine 1998). However, in the daily life of academic institutions, there are many situations where the most common is the availability of small datasets. The data which is collected on courses that students take is a good example of such a situation; even if a relatively large group of students attends the course, the relevant data is usually considered a small dataset. This constraint raises an important barrier to adoption of the DM technique in the educational arena. Therefore, a likely scenario could be a wide availability of contemporary DM tools but the impossibility of using them reliably because the available data is limited and clearly falls into the category of small data sets. However, on the contrary, some researchers clearly support DM generally not being limited to large datasets. Specific use

of DM tools for structured small datasets can also offer reliable results (Nooraei et al. 2011; Natek and Zwilling 2014). Another limiting factor concerns privacy issues; in data mining projects where personal data is used, it is important for the educational management team to be aware of the legislation, all the more because data may belong to underage students.

Classification of EDM Functionalities

Peña-Ayala (2014) analyzed a sample of 240 EDM works published between 2010 and 2013. His research extended and updated previous works. According to the characteristics and objectives pursued in each publication, a classification based on EDM functionalities was proposed. Six groups were identified, the contents being of interest to academics and practitioners because of the implications for further research and for decision-making within an educational setting. The improvement of the performance of the student learning process arises as the main *leitmotiv* of most works. From the point of view of educational managers, the information acquired, thanks to the use of EDM techniques, can contribute to the development of better politics, plans, and actions at all levels. The groups of EDM functionalities identified were the following:

1. *Analysis of student modelling.* This group includes the highest number of works in EDM. Within this group, all kinds of student traits, actions, and achievements are considered as part of this functionality. The issues addressed by works in this category include instruction and learning styles, resource usage, analysis and prediction of academic achievements, student success factors, students' mental states, domain knowledge, learning trajectories, knowledge tracing, and skills.
2. *Analysis of student behavior modelling.* This group includes research focused on the analysis, description, and evaluation of student behavior. Among the issues that are subject to study and characterization, the analysis of students' contributions, persistence in online activity, careless attitudes, user-system interaction, self-adaptation, collaborative activities, solving styles, ability, outcomes, understanding, behavior, task completion, and final marks stand out.
3. *Analysis of student performance modelling.* This functionality covers research and practical works oriented toward dealing with failure, success, students' response times, time needed to solve a problem, preparation for future learning, knowledge mastered, learning progression, response patterns, and learning achievements. The goal is to aid educational staff to supervise and assess, in a timely manner, students, with the aim of anticipating adjustments. Educational management teams could find it of interest to promote this facet of DM among teaching staff to improve student performance.
4. *Analysis of assessment.* The group of EDM applications, centered on assessment functionality, has as their main goal the evaluation and control of efficacy, efficiency, and quality of the evaluation systems, as well as the inclusion of instances aimed at assessing the degree of user satisfaction of all kinds. The issues covered in this group include, among other things, the inquiry process, learned skills, discovered relationships among responses, difficulty levels of problems, student accuracy, learning activities, misunderstandings, and the merits and pitfalls of standardized tests.
5. *Analysis of student support and feedback.* This functionality aims to develop enhanced computer educational systems by means of their personalization and customization to meet students' demands. Some of the instances considered under this aggrupation include dialogue analysis, generation of hints, decision-making, customized feedback, reinforcement, recommendations, opinion about teaching behaviors, advice content, student annotations, dealing with emotions, and stimulation of competences.
6. *Analysis of curriculum, domain knowledge, sequencing, and teacher support.* This functionality represents heterogeneous tasks and components. This group includes

those instances that do not fit into previous classification, although they cover important facets of the educational process. Among the topics addressed include content authoring, knowledge description, teachers' collaboration in tailoring curricula, personalized searching of educational content, user-tool interaction, curriculum analysis, scheduling of learning activities, design of hierarchical content structures, and teacher mentoring behaviors. Peña-Ayala (2014) expects that the evolution of this sort of functionality will see an increasing demand in academic interest.

Implications for Educational Management

An educational institution maintains and stores various types of student data; it can range from student academic data to their personal records, including parents' incomes, qualifications, etc. This repository can potentially allow managers and teachers to extract useful information in order to make management-level decisions. Although the scope and implications of managerial decisions is not the same, depending on the decision-maker (e.g., educational manager or teacher), both actors can greatly influence the quality of the teaching-learning process. Decisions at the educational management level can lead to actions such as the construction of new facilities to respond to social and educational demands, hiring new staff with specific expertise or skills, developing programs for the deeper involvement of parents, etc. On the other hand, decisions at the teacher/instructor level are more limited in scope but can equally contribute to the improvement in quality of the teaching-learning process in the classroom (e.g., rapid response to abandonment attitudes, student success predictions, etc.). Therefore, EDM should not be conceived of as a technique aimed at a specific actor within the educational arena; it is of interest to all those who can, at their own level of influence, contribute to a better performance of the educational process.

The functionalities of EDM described in the previous section obey actions that can be promoted either at the teacher/instructor level or at the managerial level. The management of schools and colleges and, of course, the management of government bodies have a wider capacity to influence and convince researchers and practitioners to learn about and adopt the EDM technique. The literature shows that the adoption of EDM has contributed to improving the educational process by, for example, (i) predicting students' performances using a dataset consisting of students' gender, parental education, their financial background, etc.; (ii) predicting student learning outcomes based on attributes such as attendance and performance in class tests and assignments; (iii) student modelling using the educational history of students; and (iv) predicting the academic dismissal of students and the GPA of graduated students in e-learning, using regression analysis and classification (Dutt et al. 2017). These evidences show that EDM can, in a broad sense, arise as an important tool for improving the work of educational managers.

Summary

EDM has emerged as a paradigm oriented toward designing models, tasks, methods, and algorithms for exploring data from educational settings. The potential opportunities provided by EDM, which claims new paradigms for enhancing the scope, quality, efficiency, and achievements of educational systems, are promising in the field of education due to it being a high priority for global society. In recent years, a wide array of tools has emerged for the purpose of conducting educational data mining (EDM). These tools have proven their utility with respect to common data pre-processing and analysis steps in a typical EDM project. Educational management should consider EDM as an opportunity for improving the quality of decision-making, both at their level and at the teacher/instructor level, thanks to its potential for discovery of hidden patterns of information; thus, their involvement is crucial

in order to take advantage of this paradigm. However, this technique shows some limitations that must be taken in consideration so as not to encounter the potential pitfalls that, in the long-term, may end up causing mistrust and doubt regarding the usefulness of EDM.

Cross-References

- [Educational Assessment, Educational Data Mining, and Learning Analytics](#)
- [Multimodal Learning Analytics](#)

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Data Protection

- [Security and Privacy of Information Technology Management Systems](#)

Data Science

- [Data Science Education](#)

Data Science Education

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Synonyms

[Big data](#); [Data literacy](#); [Data science](#); [Data science education](#); [Data science education curricula](#); [Deep learning](#); [Ethical issues of machine learning and big data](#); [Machine learning](#); [Social effects of the application of data science methods](#)

Data science is the art and science of turning data into insights. Data science is a cross-disciplinary area that applies various concepts, methods, algorithms, and processes from diverse scientific

disciplines, like mathematics, statistics, computer science, and information science. Data science aims to apply these methods and concepts employing suitable integrated development environments and tools to generate knowledge from partially unstructured, incomplete, and distributed data collections. Depending on the application context, this knowledge can then be transformed into concrete action, e.g., when companies make strategic decisions on future business policy based on trend analysis (Song and Zhu 2017; Parks 2017).

In order to correctly assess the significance of data science education (DSE) in education and training at schools and universities, it is necessary to firstly deal with technical concepts of Data Science (DS) and Big Data and their areas of application as well as their social and economic impacts in society.

Subsequently, considerations can be made as to how technical contents and methods of data science can be integrated into existing curricula of schools (e.g., mathematics, computer science, STEM, social, and cultural science subjects) and universities (computer science, science, social sciences, humanities, ...) or whether DSE/DS should be an independent subject in schools or universities.

A look at the current literature shows that there are slightly different definitions for DS and Big Data. Also, the field of applications of methods and concepts of DS is vast and diverse and covers many social and scientific areas.

Data Science

Therefore, the following aspects of DS will be considered:

- The data sets used (Big Data, partly unstructured data from different sources, handling of probability values of data, handling of uncertainty and missing data, ...)
- The computational and mathematical methods used in Data Science (e.g., machine learning, deep learning, artificial intelligence, algorithms, neural networks, self-optimizing genetic algorithms, probability theory, stochastics)
- The technological methods of data collection, processing, storage, distribution (e.g., data from business processes, data from production processes, data streams from sensors, social networks (user-generated data), (self)-tracking, open statistical sources, health care, ...)
- The application areas of Data Science in society and the social, ecological, economic, political, and ethical issues
- Data mining process models (e.g., CRISP-DM)

In the following, some mathematical, statistical, computational, technical, and human-social aspects of Data Science will be discussed in more detail, see, e.g., Blei and Smyth (2017).

Big Data

In a society characterized by increasing digitalization, a wide variety of communication, interaction, and production processes are leading to the creation of extensive, distributed, and independent data collections. In contrast to structured data collections, as we know them from traditional computer science databases, these data are entirely different or not at all structured and sometimes even incomplete. These databases are often referred to by the generic term “Big Data.” In the literature, there are different definitions, which nevertheless refer to essential common characteristics of Big Data (DejaVVu 2012; Chen et al. 2014; De Mauro et al. 2015; Alharthi et al. 2017; Zhang et al. 2017).

Such a consensual definition of big data usually contains the following properties of Big Data, described as the “5 Vs” (see Zhang et al. 2017):

Variety represents the different data types gathered from various sources. The data types are mostly multiplex and consist of, e.g., text, symbols, images, videos, audios, and sequential data streams from sensors.

Velocity characterizes the speed at which the data is generated, transferred, and has to be processed. Some applications can access stored data in batch mode and are not time-critical, while others require continuous real-time processing of the data, sometimes at high speed.

Volume represents the huge amount of data produced from different sources.

Value addresses the (hidden) information contained in the data. From this extracted information, knowledge can be generated that can be of great use and value to individuals or organizations. Value is about understanding the meaning of the data for a specific application context. This understanding of meaning can lead to economic gain but also to political or social advantages for those who have access to this knowledge. This aspect concerns the relationship between data, information, and knowledge, as well as the question of user interests and accessibility to these large databases.

Veracity concerns the increase of the quality of data and the extracted information. Since the data originate from different sources, they must be appropriately combined and analyzed, and the results must be verified concerning their trustworthiness. Data may be incomplete, and the reliability of the data is not assured. The processing of big data, therefore, requires the handling of uncertainty, probability values, and missing data. Only in this way, a new quality of the aggregated data can be achieved and thus a qualitatively higher benefit for the users.

The access and analysis of Big Data place high demands on the evaluation methodology and the IT-infrastructure.

Data Sources

In a society characterized by digitalization and globalization, data is generated by a variety of processes in very different areas.

In companies, communication and cooperation processes can result in large amounts of data. On the one hand, they concern internal communication and production processes. On the other hand, they also concern communication with other companies (B2B) or with customers (B2C). Some of this data is only available within the organization, and others can be used by other users. The data form an essential information basis for the organization of the enterprise and the planning of its future business activities.

In addition to documents of various types, employees also generate digital artifacts resulting from their communication in various digital media, such as email, chat, articles in wikis and group communication tools, group calendars, etc. In this way, cross-company artifact actor networks (AAN, Riss et al. (2011)) are created, which can also represent a valuable data sources.

Another essential data source is scientific institutions with their research results published in various media.

Furthermore, numerous governmental and private organizations (e.g., NGOs) publish data from their respective fields of activity (e.g., statistics on government action, social statistics, regional and global economic data, ecological data on the state of the environment, statistical data from the health sector, etc.).

A further group of data sources is process-data provided by different technical-physical sensors. These include, for example, measurements from the environment, such as weather data, climate data, data on water quality, air pollution, etc.

The Internet of Things (IoT) and the close collection of data in residential areas (Smart City) and households (Smart Home) generate further massive databases. The 5G-technology enables very fine-grained motion profiles of people (tracking of mobile devices, self-tracking) and vehicles (toll, autonomous driving), which are also based on the generation of large data pools.

The use of the Internet with its wide range of services is also a source of vast data collections. In addition to video and audio streams from various Internet platforms and websites, it is above all the data traces voluntarily (user input) or involuntarily left behind by users (tracking) that generate immense amounts of data. In particular, the posts and likes left behind in the social media (e.g., Twitter, Facebook, etc.) as well as the usage data, often hidden collected by apps on mobile devices (evidence of mobile apps), offer various interested parties a variety of evaluation options.

Many of these sources are publicly accessible or are available for assessment for a fee.

For DSE purposes, some data sources, mentioned above, are also available and can easily be exploited in a wide variety of subject areas,

especially from Open Data Sources (Gandomi and Haider 2015; Katal et al. 2013; Deokar et al. 2018; Ruijter et al. 2018).

Methods of Data Science

In order to use these distributed, unconnected semi- or unstructured data collections and to extract hidden patterns and information, a combination of mathematical, statistical, and informatics methods is required. In order to select the correct evaluation strategies concerning the evaluation interest, to pose the basic appropriate evaluation questions and to interpret the meaning of the gained information correctly concerning the evaluation context, domain-specific context-related knowledge is also required.

It follows from this that there is no generic uniform methodology of DS, but in each case, a combination of methods appropriate to the question and the complexity of the data collection is necessary.

Besides a phase model, which determines the sequence of individual evaluation steps (see below), above all methods of the field of artificial intelligence (AI), like machine learning (ML) and deep learning (DL), are to be called here. AI functions as a generic term for the application of different mathematical and informatic methods to which logical methods and knowledge-based systems also belong.

Machine learning (ML) mainly applies different mathematical methods in order to structure data collections in a hierarchical order, e.g., as a decision tree. Also, the clustering of data or rather data vectors, according to similarities, is an often-used method.

Their goal is to recognize patterns in the data. Furthermore, statistical methods are also used if a complete analysis of the data sets is not possible due to missing or insufficient data or too many dimensions to be considered. In this way, it is possible to essentially reduce the number of data dimensions to be considered in machine learning.

According to the laws of probability theory, only the most “probably” useful dimensions are considered concerning the domain of knowledge,

which considerably reduces the calculation effort (feature engineering) (Reid Turner et al. 1999).

In machine learning and feature engineering, the problem of unequal treatment of learning algorithms must also be considered (process fairness in ML), so that self-reinforcing effects do not prevent satisfactory results (unbalanced predictions, automated decision-making). To solve these issues, performance metrics for ML models are generated and applied. Furthermore, it is possible to influence the weighting of certain variables in the calculation models by targeted human intervention based on domain-specific knowledge.

In deep learning, a specific discipline of machine learning, neural networks are also used to find relevant patterns in the data collections or for pattern recognition in addition to the methods mentioned above.

In the broadest sense, neural networks are based on biological concepts of information processing in the brains of living beings. Data and information are realized by the connection of neurons, which can be represented as graphs with nodes and edges. By developing new or deleting other connections, adjusting the weights of the connections between the neurons and changing threshold values above which connections are considered relevant, calculations can be carried out on the computer in many iterative steps, which may then lead to the discovery or recognition of patterns (Al-Masri 2019).

Backpropagation networks consist of an input layer of neurons of an output layer and one or more intermediate layers.

Neural networks are fed (trained) with data utilizing an activation and input function, while propagation and output functions are responsible for the calculation of state changes in the network or the output of the calculated values and information.

By training a neural network, the weights between the neurons can be adjusted for pattern recognition, so that specific input patterns (e.g., photos of a person) always lead to a particular output pattern (e.g., recognition of the person).

Convolutional neural networks (CNN) are specific neural networks that are mainly used for the classification of image data. In order to reduce the

computational effort for the pixel data of images, these networks are preceded by computation methods that reduce the effort before the neural network is applied (A Beginner's Guide to Neural Networks and Deep Learning 2019).

Algorithm models for classification or regression are most frequently used in combination with neural networks for supervised machine learning. However, models for unsupervised learning are also used, which include methods of clustering and dimension reduction. In supervised machine learning, functions are calculated on the basis of training data whose output is known (pattern recognition). In unsupervised machine learning, previously unknown structures in the data are to be extracted without the specification of a target variable.

Overall, the described methods of ML and DL are mainly based on the combined application of mathematical and informatics methods. From the field of mathematics, there are subareas such as proposition and predicate logic, relational algebra and graph theory, as well as search and optimization methods, which in turn are based on concepts of linear algebra and analysis. Other important mathematical disciplines required for the methods of Data Science are probability theory and stochastics. From a computer science perspective, the methods of Data Science mainly include the fundamentals of modeling and programming, algorithms and data structures, databases, software development, and software architectures.

In Data Science methods, it is difficult to distinguish between mathematical and informatics parts of the methodology, because there is a high degree of overlap between the two parts. From a computer science perspective, it is particularly important that the data is machine-readable and can be processed with suitable software tools and a powerful hardware architecture. In order to be able to develop appropriate problem-related questions and to adequately evaluate the results achieved against the background of the application context, a third field of knowledge beyond mathematics and computer science is required: domain-specific expertise. Thus, it becomes clear that DS is not only a field that requires multiple

methods but also a multi-perspective view of the problems by experts from different fields. These different requirement areas for DS will later also be considered in the design of DSE curricula at school and university in an appropriate form and in relation to target groups (see below) (LeCun et al. 2015; Blum et al. 2018; Al-Masri 2019; Nielsen 2019; Maimon and Rokach 2010; Schmidhuber 2015; Chattamvelli 2016; Artificial Intelligence 2019).

Data Mining Process Models

The use of mathematical and informatic methods, as well as the application of domain-specific knowledge during the preparation and analysis of data, must be sensibly integrated into an overall concept of data mining appropriate to the problem and in order to achieve useful evaluation results.

This process-related aspect of data-handling can, on the one hand, be viewed from the perspective of the data (data life cycle) and the associated activities of data preparation. On the other hand, it can be regarded from the perspective of business and working processes and the associated evaluation interests (data mining process models). Both partly empirically founded concepts show a particular agreement with some differences in the detail.

The activities of data manipulation assigned to these phase models can be linked to phases of learning in DSE projects and the competency requirements to be acquired there. These phase-related activities can then also serve as elements of a theoretically founded competence model or to justify DSE curricula (see below) (Faundeen 2012; U.S. Geological Survey et al. 2017; Data Life Cycle 2019; Sivarajah et al. 2017; Wirth and Hipp 2000).

The models partly are of different granularity, partly consider technical aspects of the implementation of concepts of data processing and therefore contain a different number of elements.

The data life cycle model, which is based on a project funded by the US National Science Foundation, comprises eight phases (see Data Life Cycle 2019):

- **Plan:** Description of the data that will be compiled and how the data will be managed and made accessible throughout its lifetime.
- **Collect:** Acquisition of the data (e.g., by hand or with sensors or other instruments; the data are transferred in a machine-readable form).
- **Assure:** The quality of the data is assured through checks and inspections that includes cleansing of the data.
- **Describe:** Data are accurately and thoroughly described using the appropriate metadata standards.
- **Preserve:** Data are submitted to an appropriate long-term archive (i.e., data center).
- **Discover:** Potentially useful data are located and obtained, along with the relevant information about the data (metadata).
- **Integrate:** Data from disparate sources are combined to form one homogeneous set of data that can be readily analyzed.
- **Analyze:** Data are analyzed in order to extract relevant information.

Other concepts additionally amended further phases including some technical aspects of data handling (see, e.g., Grillenberger and Romeike 2017, pp. 35).

- **Model:** Structuring the data in a way that it can be stored and accessed efficiently.
- **Implement:** Implement the data model and store the digital data.
- **Visualize:** Visually presenting and editing information to make them better understandable.
- **Evaluate:** For example, the analysis results and the quality of data they are based on.
- **Share:** The data (original or aggregated data) and/or results of the analysis.

Other, somewhat more complex models also emphasize the importance of integrating external expertise into the evaluation and application process as a cross-phase necessity: “Community Watch & Participation” see (DCC Curation Lifecycle Model 2019).

The preparation and evaluation of the data in the data life cycle can be structured according to

another model concerning three groups of challenges (Sivarajah et al. 2017, p. 265).

- **Data challenges:** The group of the challenges related to the characteristics of the data itself (see above: volume, velocity, variety, variability, veracity, visualization, and value)
- **Process challenges:** Encountered while processing the data (data acquisition and warehousing, data mining and cleaning, data aggregation and integration, analysis and modeling, and data interpretation)
- **Management challenges:** Tackle, e.g., the privacy, security, governance, and lack of skills related to understanding and analyzing data

Concerning the evaluation and application interest of companies and organizations with the perspective of determining concrete action strategies, the use of analytical methods in the context of Big Data can be divided into the following phases: (Sivarajah et al. 2017, p. 266).

- **Information:**
Descriptive analytics that help in understanding, e.g., “What happened in the business?”
Inquisitive analytics that help in comprehending, e.g., “Why is something happening in the business?”
- **Insights:**
Predictive analytics that help in anticipating, e.g., “What is likely to happen in the future?”
- **Decision:**
Prescriptive analytics that help in responding “So what?” and “Now what?”
- **Action:**
Preemptive analytics that help in recommending “What is required to do more?”

There are various data mining process models with different phases, especially for the preparation and analysis of Big Data and its use for strategic entrepreneurial action.

The iterative and interactive KDD model (Knowledge Discovery Databases) has nine steps. The SEMMA (Sample, Explore, Modify, Model, Assess) model was developed by SAS institute and has five different phases.

The best-known Data Mining Process Model, which has been repeatedly refined over the years, is CRISP-DM (Cross-Industry Standard Process for Data Mining).

It originally was launched in late 1996 by Daimler Chrysler (then Daimler-Benz), SPSS (then ISL), and NCR and has six steps or phases: business understanding, data understanding, data preparation, modeling, evaluation, and deployment (Shafique and Qaiser 2014).

These phases can be applied in different order, and repeatedly, as data mining is seen as a cyclic process. Each phase describes specific tasks and aspects of the process, and thus can also be used to describe affordances for a data science curriculum. Therefore, in the following, each phase will briefly be discussed (see Wirth and Hipp 2000).

Business Understanding

This is an initial phase focusing on understanding the objectives and requirements from a business perspective, in other words: understanding the problem domain. This phase aims at uncovering important factors like success criteria, business and data mining objectives and requirements, as well as business terminologies and technical terms. Developing a preliminary project plan, designed to achieve the objectives, is also part of this phase.

Data Understanding

This phase typically starts with data collection and checking the quality of the data. Exploring the data for hidden information and deriving hypotheses are also important tasks of this phase.

Data Preparation

This phase focuses on the selection and preparation of final data sets. Tasks of this phase include table, record, and attribute selection, data cleaning, construction of new attributes, and transformation of data for modeling tools (construct data; derive attributes; integrate, merge, format or reformat data). During this phase also a rationale for inclusion/exclusion of data should be generated (data set description/data cleaning report).

Modeling

In this phase, various modeling techniques are selected and applied in order to build a model, according to modeling assumptions. Also, the development of a test design and the application of tests in order to assess and possibly revise the model and its parameter settings has to be conducted during this phase. Since some techniques require specific data formats and there is a close link between data preparation and modeling, it is sometimes necessary to construct new data.

Evaluation

This phase focuses on the evaluation of the obtained models, and it is to decide about the quality of the results with regard to the data, the applied algorithms and if the model will be able to achieve the business objectives. At the end of this phase, next steps and a list of possible actions should be determined based on the model and the data analysis.

Deployment

In this final phase, the gained knowledge has to be delivered and presented to the customers.

This can be done by a simple final report or in a more complex way that includes a presentation of the results and the delivery of documents (e.g., project review, monitoring and maintenance, and further action plan) that allow the implementation of a repeatable data mining process.

Application Areas and Social Impact

The consideration of process models for the analysis of big data and the extraction of relevant information has so far mainly been related to the area of companies and organizations. However, the presented process models can also provide important clues for the methodical and content-related design of DSE projects and the competences to be acquired by learners. However, DSE must not only refer to the mathematical, informatics, and technical aspects of data science but should in any case also consider the social effects of the application of DS concepts in society. This applies both to the training of DS professionals in higher education and to DSE at the secondary level. Both DS-professionals and

students should be aware of the social impact of DS in society in responsible informatics-system design (professionals) as well as in a competent political and social participation in society (students). A basic understanding of the social effects of the application of DS methods requires at least a basic knowledge of these methods.

Social impacts of DS affect many areas of society that cannot be described in detail here. It is essential for the content selection of the topics in DSE at the secondary level that they relate to the reality of the students' lives. In order to gain an overview of the diversity of possible topics, the social impact of applications of DS methods can be structured according to different aspects:

- Structuring according to the complexity of the social context
- Structuring according to social areas of application
- Structuring according to social impact type

In order to analyze a DS application scenario and assess its social impact, the dimensions can also be combined and thus open up a multi-perspective view of a selected subject area. These structural dimensions are not disjunctive and partly condition each other in a complementary way (see below).

Structuring According to the Complexity of the Social Context of Application Scenarios

Depending on the complexity of the social context of the application scenario, the use of DS-concepts has an impact on the individual level, on the level of groups, an organization or a company, on the whole society, or even on an international or global level. These effects are often only to be understood in the interdependent interaction of the different levels and complement each other.

For example, the use of voice-controlled, networked assistants in a Smart Home can provide useful services to the residents of an apartment. On the other hand, residents can transmit a large amount of private data to the service provider either intentionally or unintentionally. These processes could violate the privacy of the residents. In a complementary way, an internationally or globally

active company that collects such data in a large number of households can build up a massive data collection. This data can then be used to provide private households, for example, with user-specific information (recommender systems, targeted advertising). On the other hand, the company can use this data for the further development of its own corporate strategy or sell the customer data profitably to other interested parties.

Structuring According to Social Areas of Application

There is a multitude of social application areas in which DS methods and concepts are used. Here, too, the application areas cannot be considered entirely independently of each other, and their effects overlap or influence each other. These societal domains can be regarded as necessary:

- *Economy*: For example, economic data of companies, states, associations of states in order to obtain action strategies for controlling the economy at a particular level (corporate strategy, state, and supranational economic policy).
- *Energy*: For example, data to control complex energy system depending on generation and consumption of energy.
- *Environment/ecology*: For example, environmental and weather data that can be used for weather and climate forecasts.
- *Disaster response*: For example, data from catastrophic events (storms, earthquakes, floods, and volcanism) to develop strategies to avoid or reduce risks.
- *Healthcare*: For example, behavioral and health data of individuals as a basis for research into the causes of diseases, a system for diagnosing diseases based on pattern recognition.
- *Politics*: For example, statistical data from various sources as a basis for strategic political decisions.
- *E-government*: For example, ADM-algorithms (automated decision-making) for automated processing of administrative procedures. Based on training data, group membership correlates with the target variable. ADM concepts can be used to make decisions for cases and groups to be treated in the same way.

- *Education*: For example, data from learners in e-learning systems (learning analytics).
- *Traffic*: For example, intelligent traffic systems, autonomous driving based on 5G data.
- *Smart Home, Smart Cities*: For example, user data of services offered in households and communities to control the use of service offers.
- *Culture*: For example, the use of video data from many films to generate any artificial scenes with the persons concerned, which cannot be distinguished from real scenes.
- *Life style*: For example, data generated in social media, which can be used for very different purposes (e.g., control of media usage by consumers).

Micro-targeting should be mentioned here as another example of the mutual relationship between social complexity and societal DS-application areas. Through the systematic analysis of data from social media, as well as on voter behavior and opinion research, specific target-group-related advertising measures to influence political opinion can be developed. This strategy can be realized, e.g., by posts in social media, which are only visible for a specific target group and whose opinion is reinforced in the groups' typical "filter bubble." In this way, e.g., elections can be decided at the national level.

Structuring According to Social Impact Type

The types of social impacts of DS-applications can be classified as follows:

- *Economic*: Employment, changing economic strategies
Based on the analysis of economic data or data from social media (trend analysis), entrepreneurial or governmental decisions can be made that can lead to redundancies for members of the target groups affected, but also to demand labor.
- *Political*: Political abuse and surveillance versus improved decision-making and participation

Through a mass collection of personal data, including movement data of persons (tracking, surveillance, self-tracking) in combination with pattern recognition of video recordings

provided by cameras installed in public areas, copious social control and surveillance of people can take place.

- *Social and ethical*: Participation, equality, trust, discrimination (exclusion, inclusion)
The analysis of data obtained in the above manner using DS methods can lead to the exclusion or inclusion of groups of persons, e.g., concerning state or entrepreneurial action. (Social monitoring and reward or restriction systems; access or exclusion of groups of persons concerning insurance benefits, loans or health care measures).
- *Legal*: Privacy issues, intellectual property rights (IPR), liability, and accountability.

The personal data collected on a broad basis can lead to their misuse and the violation of personal rights. This also applies to the handling of IPR, which address an essential aspect of data management. If such rights are not observed, the relationships between powerful economic or state actors and individuals can be damaged. This then affects questions of liability and accountability.

Concerning the data generated (provided, observed, derived, and inferred) (OECD 2014) and decisions made by ADM or algorithms based on DS methods, a distinction can be made between different ethical issues, which imply different social consequences:

- Inconclusive evidence (probable yet inevitably uncertain knowledge) leading to unjustified actions.
- Inscrutable evidence (lack of knowledge regarding the data being used, e.g., relating to their scope, provenance, and quality) leading to opacity.
- Misguided evidence (conclusions can only be as reliable as the data they are based on) leading to bias.
- Unfair outcomes are leading to discrimination. Actions driven by algorithms can be biased concerning numerous ethical criteria; also, the iterative calculation steps of algorithms may not guarantee fairness to the different branches and outcomes.

- Transformative effects are leading to challenges for autonomy. Algorithms, e.g., like profiling, re-ontologize, and conceptualize the knowledge domain the related real-world problem sometimes in new, unexpected ways. The results could trigger actions based on the insights it generates, though the calculation processes have not been transparent.
- Transformative effects are leading to challenges for informational privacy. The lack of transparency of some results generated by DS-methods implies that harm caused by algorithmic activity is hard to debug but also that it is rarely straightforward to identify who should be held responsible for the harm caused (e.g., exclusion from a governmental service; car accident during autonomous driving) (Mittelstadt et al. 2016; Gupta et al. 2018; Mantelero 2018; Lepri et al. 2016; Cuquet et al. 2017; Bigdatasoc 2019; Trajtenberg 2018).

Informatics Systems for Processing Big Data

The application of DS-methods always requires Computer Science knowledge about the software and the hardware of the analysis environment and the embedded analysis tools. Depending on the size of the company or organization, there is a wide range of complexity of the systems and the skills required to use them.

In large companies/organizations, knowledge of system enterprise architecture with its hierarchical, aggregated layers (e.g., Multilayer Model: Technology or Infrastructure Architecture, Software, Integration, Process, and Business Architecture) and the data flows caused by it is essential for the analysis and evaluation of the data (see Winter and Fischer 2006; Kearny et al. 2016; Niu et al. 2013).

Specific working environments or tools are used to collect the data, to store the original and processed data, process and visualize the data, and manage data storage and distribution sustainably. These different phases of tool's usage of the informatics working environment are closely related to the phases of the data life cycle or the phases of

the DM-process models and are used there repeatedly as required.

Standard software tools and architectures can be assigned to specific phases of the DS-DM process.

Collect Data

In this phase, access to internal data streams and data collections as well as to external data sources is required. These activities require knowledge of relational and non-relational database systems (e.g., NoSQL, MongoDB) and database languages (e.g., SQL). For access to external data sources (e.g., social media) and the subsequent restructuring of the data for evaluation purposes, access to available interfaces must be mastered (Bello-Organ et al. 2016; Ahmad et al. 2017).

Depending on the system architecture and the available tools, this requires additionally knowledge of XML, PHP, Java, C#, JavaScript, JSON, Python, etc.

Edit Data with DS Methods

In order to process extensive, sometimes unstructured data collections from different sources applying DS methods, several computing environments, available on the market, can be used. For data preparation, parallel data processing methods and more massive computer clusters are used in large companies and organizations. Free software libraries to accomplish these tasks include MapReduce, Hadoop, Mahout, etc. (Bello-Organ et al. 2016).

MapReduce is designed for implementing algorithms that allow distributing parallel processing. It divides problems into two parts by using two basic functions, mappers and reducers. The map function processes source data into sufficient statistics. The reduce function merges all sufficient statistics into a final result. Thus, any number of concurrent map functions can be processed at the same time without intercommunication.

Hadoop is a scalable framework designed for the distributed processing of large data sets across clusters of computers. It enables preprocessing procedures like filtering, sorting, and generate denser data that might contain more information and make the data suitable for additional analysis with other tools.

The scalable Mahout machine learning library enables the implementation of numerous ML-algorithms for dimensionality reduction, classification, clustering, etc. Additionally, it contains topic models and a set of recommender systems for user-based and item-based strategies.

Furthermore, several program packages and integrated development environments are available, which can be used to further evaluate the data after preprocessing or immediately apply DS methods.

These packages include, for example, the open source programming language R for statistical calculations, the language “R Markdown” for the creation of problem-oriented result reports, and the associated integrated development environment R-Studio. The latter can be used to coordinate more complex calculations with the data and visualize the processes and results and output them in different document formats. The packages also have numerous interfaces to other tools for further analysis of the data (e.g., Jupyter Notebook, see below.) (Bello-Orgaz et al. 2016).

In the simplest case, however, generic tools such as spreadsheets can also be used for the calculation and visualization of data.

If, for example, neural networks are to be integrated into the machine learning process for pattern recognition or similar evaluation tasks, appropriate development, and training tools are also available. These include, e.g., Tensor Flow, PyTorch, Keras, OpenNN, Neuroph, Neuronal Designer, and others (see The Best Machine Learning Tools 2019; Richard 2019).

Here are just a few examples of the essential functions of TensorFlow. TensorFlow is an open source software library for large-scale machine learning and deep neural network research. It applies data flow graphs consisting of nodes and edges for numerical computations. Nodes in the graph represent mathematical operations, and edges symbolize multidimensional data arrays or tensors, on which these operations are performed. TensorFlow enables the visualization of data flow between operations and thus can contribute to a better understanding of the calculation processes. Among other things, this property makes the computing environment

particularly suitable for learning with neural networks in DSE (see below).

Sustainable Storage, Backup, and Distribution of Data and Results

For the sustainable saving and archiving of raw data, prepared data and evaluation results as well as their distribution, a hardware and software architecture are required, especially in large companies and organizations. This includes storing of data in repositories with version control like, e.g., Github, Hadoop, OpenStack, Swift, and many others. In particular, access rights management, privacy and security issues, as well as the compliance with IPR specifications, have to be considered. This results in further competence requirements of data science (Rimal et al. 2011; Chen and Zhao 2012).

Data Science Education

In this section, we discuss data science curricula to give an impression of the nature of the data science education mainly at school but also in academia. To give the reader an overview, we focus on the rationale (Annette Thijs and Jan van den Akker 2009), that is the underlying philosophy of the curriculum.

In accordance with the evolution of data science out of statistics (Hardin et al. 2015), data science curricula often emerged as part of statistics curricula. Hardin et al. give an overview on data science curricula in a statistical context, thereby focusing on the specific nature of the new curriculum aspect, which is (a) the inclusion of programming competencies beyond simple scripting and (b) the inclusion of data technology and data formats in contrast to statistics education, where questions of data management and data wrangling are often omitted in order to focus on the statistical aspects. Nevertheless, statistics should be included, and therefore data science curricula typically center around a data process and “real” authentic data examples.

In general, typical current curricula are aligned to the data life cycle and process models, e.g., the CRISP-DM (De Veaux et al. 2017). That is, the curriculum organization is in some way related to

the phases and tasks of such models. This includes the notion that data science curricula include data science projects to allow learners to experience the full data life cycle. In this context, it is often suggested to also include “real data” and “real” project, e.g., projects with some real-world application (Song and Zhu 2016). Examples are data science for social good. In addition, data science curricula are aiming at integrating computational as well as mathematical (statistical) skills (topics).

In an overview study, Ridsdale et al. (2015) summarize typical curricula around the data science process with the aspects of: data collection, data management, data evaluation, and data application. For each of these phases of a data science life cycle (they call them key abilities) related competencies and tasks/knowledge are described. For example, “data collection” as key ability is refined to competencies of “data discovery and collection” and “evaluating and ensuring quality of data and sources.” The first of the competencies (Data discovery) is detailed to the tasks of performing data exploration and identifying useful data. On the finest level, a data science curriculum thus defines operations with or on data, see, e.g., Erickson et al. (2018).

DSE Project Models (Related to Data Science Process Models/CRISP-DM)

Project phases as defined for industrial use are not suitable to be implemented without adaptation in education. For example, depending on context and level, DSE curricula focus, e.g., more on computational aspects (e.g., safely and efficiently storing and retrieving of data) or statistical (e.g., proper choice of visualizations and tests) within project phases.

Another difference is a stronger focus on ethical issues in education. Such ethical and societal aspects of the curriculum are typically not included in data life cycles. For example, Ridsdale et al. add competencies like “Critical Thinking,” “Data Ethics,” or “Evaluating Decisions Based on Data” to the list of competencies and thereby enrich or change the phase “Data Application” which in the CRISP-DM is just seen as “Deployment.” Similarly, Song and Zhu (2016) change the CRISP-DM and split modeling into the phases model planning

and model building, and add the phase “Review and Monitoring” to account for the educational context.

In the following, we will briefly discuss differences in these project phases due to the educational context, briefly referring to the CRISP-DM (see above).

DSE-Project Phases Related to Business Understanding

In this initial phase, an outline or plan for the project will be developed including, e.g., understanding the problem domain and setting the goals. In education, this phase might differ. For example, from the history of statistics education and also in models of data literacy, this step is usually conceived as asking a question or posing a problem to be answered by data; but the question or the context within to find a question to be answered is chosen for suitability for the educational goals. While it is obvious that domain-specific expert knowledge is necessary for its successful design, it may be that domains are chosen that are well-known to the learners, so that they can focus on learning the data science aspects.

DSE-Project Phases Related to Data Understanding and Data Preparation

The next two phases are probably more connected in educational projects.

Again, from the history of statistics education, the task in the phases of data understanding and preparation is typically seen as specifically collecting data to answer a given question, e.g., by designing a questionnaire and conducting a survey. From a CS perspective, another typical approach would be to look at data already being collected – either with the intention to explore and understand the data, or to answer some specific questions. Typical data sources for this type of data science projects include data from sensors or from human interactions with digital artifacts. In both cases and/or in initial stages of the curriculum, the task to prepare the data is often omitted, and cleaned data is given to the learners, so that they can focus on data understanding. In order to achieve an authentic learning experience, it is

often suggested to use real data and real data projects, so that it “smells like data science.” In industrial projects, 70% or even 80% of the time can be spent with data management, including data understanding and data management: e.g., data wrangling, data transformation, coping with missing values are a prerequisite then for first visualizations and descriptive statistics. For educational projects, it does not seem suitable to use such an amount of time for data preparation. So pre-cleaned data, smaller data sets can be used to reduce the length of this phase. Typically, first projects are done with ready prepared data sets. In textbooks and libraries for data science, often such cleaned data sets are already included. So, in education, this step is rather tightly coupled with data preparation, that is, e.g., selecting data to be used for the next phase.

Data understanding is a very crucial part and includes basic descriptive statistics and data visualization, e.g., visual analytics.

DSE-Project Phases Related to Modeling and Deployment

In this phase, new insights from the prepared and selected data are to be derived. This is often connected to building a model of the problem domain, based on the data. This can be, e.g., an artificial neural network trained by the data, the result of a regression analysis, etc.

In case of a neural network, the model consists of both the overall architecture, and the specific weights of neurons based on the training phase. This model then exists independently from the data and can be used to analyze new data. It is an important insight for learners to understand that data-driven products are making decisions on cases (based on data) but doing so is grounded in past data and past cases. In addition, such a data-driven product – e.g., a recommender system – can also be adapted while in use and the model updated based on new data.

Within this perspective, the goal is then to build a product, based on the model, that can later be used. If a data-driven product is built, based on the model, then its use is referred to or prepared by the deployment phase. In data education, typical examples are projects that aim to be

effective in the students’ everyday contexts. Here projects like “data science for social good” are examples (Coulton et al. 2015; Bryant et al. 2018) or <https://dssg.uchicago.edu/projects/>.

Examples of project themes used in data science education are listed below:

- The evaluation of microblogs (tweets) regarding specific topics (hashtags) and the time course of their occurrence. For this purpose, interfaces can be used to access the raw data (e.g., <https://developer.twitter.com/en/docs>) or apply already existing analysis tools (e.g., <https://www.talkwalker.com/de/blog/7-kostenlose-twitter-analyse-tools-empfohlen-von-experten>).
- Content- and time-related analysis of communication (via different media) in accessible parts of social networks (AAN: Artifact Actor Network Analysis; e.g., Riss et al. 2011).
- Forecast of sports results, development of stocks based on past performance.
- Conducting election forecasts based on previous data and surveys conducted by the students (e.g., <http://www.bpb.de/lernen/grafstat/grafstat-bundestagswahl-2013/144674/bundestagswahl-wahl-analyse-und-wahlprognose>).
- Evaluation of data collected by students with mobile devices concerning specific questions (e.g., scientific field excursions such as in Schaal (2011)).
- Evaluation of GPS movement data of persons, deliberately collected with mobile devices (e.g., smartwatch, bicycle computer, pedometer, . . .) with the associated medical and physiological data.
- Evaluation of traffic flow data (e.g., applying pattern recognition from webcams).
- Analysis of text documents about semantic similarity (or co-authoring, plagiarism) (Reinhardt et al. 2012).
- Pattern recognition within pictures and videos (e.g., images of drones, NAO-face recognition: see Schäfer and Schlee (2014)).
- Analysis of weather data (<https://openweathermap.org>).
- International projects concerning astronomical and physical satellite data (e.g., MyNASADATA: <https://mynasadata.larc.nasa.gov/students/>).

Data Science Education Curricula

Overall the above discussed orientation of curriculum towards data life cycle models and project does not mean that these curricula are to a huge part or overwhelmingly project based. For example, Grillenberger and Romeike (2018) present a structure for a data science curriculum that is organized in alignment to the NCTM mathematics standards and standards proposal from the German Informatics Society, that distinguish between content areas and process areas.

In academic degree programs typically, basics of the above outlined data operations are taught, and then also some small projects are conducted.

These basics often include, according to an overview conducted by Song and Zhu (2016), the following courses in a bachelor degree: Probability and Statistics, Data Mining, Programming, Discrete Mathematics, Data Structure and Algorithms, Database, and Machine Learning.

School curricula in data science are usually oriented towards data literacy. From the perspective of media and communication, Pangrazio and Selwyn (2019) distinguish four approaches to data literacy: (1) data safety and data management, (2) data science, (3) data hacking, and (4) media literacy approaches to personal data – thereby unfolding a critical view on data science as contributing to data literacy.

In an introduction to curriculum development for data science at the school, Biehler and Schulte (2018) define two roles for future students with regard to data science: either working as data scientists, and then probably having additional education on an academic level, or in the role as users, exploring existing systems, developing simple system models. They should then be able to make the black boxes more transparent and identifying underlying assumptions, including economic, political, and cultural conditions and interests. Therefore, it is necessary to take into account economic, societal, and cultural conditions and implications (Harari 2017; Weigend 2017; O’Neil 2017; Aoun 2017): “For a data science curriculum, the question is how to educate students so that they can take a thoughtful position in these debates, and on a more practical level, how to integrate societal issues with formal and technical aspects of data

science as a scientific discipline. The societal aspects include questions about providing private data to companies, critical media competence, “News competence” (dealing with “fake news”), statistical literacy (media reports including products from data journalism and scientific studies using data), and using data and/or data science for one’s own goals and in everyday situations.” (Biehler and Schulte 2018). In summary, a DS curriculum for schools needs to take into account the following aspects: the fundamental ideas of data science as a discipline and the societal debate and impact of data science on society as a whole (Mau 2019) and individual life – and therefore the curriculum has also answer how it contributes to general education and the formation of the individual self. Biehler and Schulte (2018) thus proposes to conceptualize data science education and data projects in the context of so-called “hybrid” systems (Biehler and Schulte 2018; Schulte and Budde 2018; Rahwan et al. 2019). In a report on the future of jobs, the consulting company Cognizant formulated the idea of a hybrid system in terms of a future job, named “Man-Machine Teaming Manager,” whose task is to “help combine the strengths of robots/AI software (accuracy, endurance, computation, speed, etc.) with the strengths of humans (cognition, judgment, empathy, versatility, etc.) in a joint environment for common business goals. [...] The end goal is to create augmented hybrid teams that generate better business outcomes through human-machine collaboration.” (Pring et al. 2017, p. 30). By replacing the focus on business with a focus on society and societal aspects in general, the impact of this view becomes more apparent for education. In Schulte and Budde (2018), a first attempt has been made to further elicit this perspective. We hope that the notion of hybrid systems helps to integrate societal aspects and to open up black boxes.

DSE Tools and Infrastructures

In order to learn or teach data science, computational tools are needed Çetinkaya-Rundel M, Rundel C (2018).

At the level of higher education, DSE tools and development environments can be used that will later be applied in the professional environment of

DS and which must, therefore, be mastered by the learners (see above). Some of these professional tools like R-Studio, Gapminder, Tableau are highly scalable and therefore also suitable for the educational use in secondary education.

For the use on the secondary level, one can broadly distinguish two types of DSE-tools:

On the one hand are interactive tools like spreadsheets, which let one directly manipulate and visualize data. For example:

- CODAP is open source educational software for data analysis. The web-based DS tool is designed as a platform for developers and as an application for students in grades 6–14 (<https://codap.concord.org>).
- *Fathom* is an easily to handle DS tool for students that quickly represent data in a variety of different and supports students in understanding math concepts like algebra, precalculus, and statistics (<https://fathom.concord.org>).
- *iNZight* is also a DSE tool especially developed for students in lower secondary schools. It has a drag-and-drop interface, which automatically detects the variable type (numeric or categorical) of the input data and thus enable students to easily create graphs of the input data (<https://www.stat.auckland.ac.nz/~wild/iNZight/index.php>).
- *TinkerPlots* belongs to the same class of DSE tool for students in grades 4 and up. It has, e.g., a sampler engine, that allows students to design and run probability simulations and visualize the results over many samples (<https://www.tinkerplots.com>).
- *Orange* is also a machine and data visualization tool for novices and experts, that allows to explore statistical distributions and even multi-dimensional data structures (<https://orange.biolab.si/>).
- *Tableau* is a more professional computing environment for the visualization and the graphical representation of data and resulting information to support data-driven decision-making (<https://www.tableau.com/learn/articles/data-visualization>).
- *Gapminder* is a data visualization tool that is dedicated to explore the massive amount of

global statistics und uses photos to give numbers a meaning and thus creating a “fact-based world view” (<https://www.gapminder.org/for-teachers/>).

On the other hand are tools like RStudio (see description above) or Jupyter Notebook, in which data manipulation is done by using programming languages like R or Python.

Jupyter Notebook: With the software tool Jupyter Notebook, one can build digital documents, which are then also called Jupyter Notebook. The tool can be seen as a programmable digital notebook, which contains texts, links, pictures, videos, and also sourcecode snippets can be integrated and executed within the document. Notebooks can be shared with other people in many different ways, exported in various formats and, for example, packed into a Github repository. Jupyter Notebook scales well and therefore runs on a desktop, in a large cloud or on a configurable multiuser server (Jupyter Hub). Therefore, this universal tool is also very well suited for the analysis and visualization of big data in DSE (<https://jupyter.org/documentation>).

The first type of tools relies on the “What you see is what you get” and “direct manipulation” paradigms, which aim to create the impression that the user directly works with the data and gets direct feedback. Programming on the other hand is more indirect, as first a set of data manipulations is coded in a formal syntax and then applied. Both approaches have their merits and fallbacks; e.g., WYSIWYG-tools are easier to use, but programming tools are better for checking how data was manipulated: one can change the script and run again on the original data. Both types of tools can be introduced and reflected on by the students.

From the computing education perspective, the intention is not only to use tools in order to learn data science (learning with tools) but also to learn about tools and their role in data analysis. Learning about tools includes understanding the role and influence different tools have on the data science process and to understand that tools are designed and constructed for a purpose – and hence that tools can be redesigned. Often, easy-to-use interactive

tools are not readily open for redesign by a user, whereas the more programming-like tools afford and inspire adaptation to one's own need.

Finally, a type of tools should be mentioned, which makes the calculation processes and the dataflow between them visible and at the same time uses neural networks for the analysis of the data. The DS-tool TensorFlow (see description above) belongs to this class of tools.

Supplemented with Keras (see Chollet 2017; The Keras Blog 2019), a simple and modular deep learning library for Python, this computing environment is also a powerful tool for data analysis in DSE.

DSE and Relation to Other Subjects

DSE: Relation to Computer Science Education

In curricula for computer science education (CSE), already aspects of data science are included. In the CSTA curriculum, e.g., the following data science-related content areas are included:

- Use data analysis tools and techniques to identify patterns in data representing complex systems. For example, identify trends in a dataset representing social media interactions, movie reviews, or shopping patterns.
- Select data collection tools and techniques to generate data sets that support a claim or communicate information.

“Evaluate the ability of models and simulations to test and support the refinement of hypotheses” (CSTA 2017), p. 27. Students shall acquire these skills according to the CSTA K–12 recommendations within the data-related topic areas “Collection, Visualization, and Transformation,” “Hypotheses,” and “Inference and Models and Algorithms.” In a conceptual description of a modern CSE curriculum in the UK, the Royal Society also emphasizes the significance of big data: “The opportunities provided by new computing curricula coupled with advances in technologies and analytical tools with which to mine big datasets, and the increasingly interdisciplinary nature of educational research, offer enormous scope for advancing computing

teaching and learning” (Royal Society (Great Britain) 2017), p. 96.

On the other hand, CSE curricula comprise essential areas of competence that are not in the focus of DSE, for example, exploring and understanding informatics systems concerning their externally visible function and their internal structure. The results of that kind of exploration will enable students to enhance their informatics systems and to design and to develop new ones. In doing so, the respective socio-technical application context of the informatics systems and the capabilities and the potential interests of the users are to be considered. These kinds of questions and fields of competence are the focus of various CSE approaches that regard informatics systems as socio-technical systems. However, as noted above, another goal of data science education is to open up the black boxes of data-driven products and systems people encounter in their everyday use of digital devices.

So far, computer science curricula tend to focus on constructing artifacts and not so much on the analysis, evaluation, and societal reflection of existing artifacts (Schulte et al. 2017; Tedre et al. 2018). This general orientation is at least in part due to the nature of the discipline of computer science itself, that also merely focuses on designing and developing artifacts (Tedre 2014), so that the idea of focusing on analyzing existing artifacts or machines, seems like a change of perspective, and as one that forces more substantially to include interdisciplinary approaches (Rahwan et al. 2019).

Another interesting relation of data science, and more specifically machine learning, is the change in the process of designing and problem solving itself. From the beginning of computing education, a core goal and rationale was the tight connection to problem-solving. Problem-solving, according to Polya (2014) is a process and an approach to find a way to overcome a barrier between the task at hand and the solution, because the immediate way how to solve the problem is often not clear. One approach is heuristic problem-solving, where a solution is designed, tested, and then refined. Heuristic problem-solving is supported by stepwise refinement and a top-down process. In structured programming,

the problem solver/programmer stepwise refines the solution from analysis, design to implementation. In a more abstract point of view, two phases are most important for this process and for education: The problem solver/learner first analyzes the problem, and second, designs a solution. The important aspect is, that the problem (analysis phase) and the solution (design phase) are needed to be deeply understood. Therefore, computer science core educational goal is learning this kind of problem-solving. In early days, it was referred to as programming, then as algorithmic thinking and also (as it is now) as computational thinking. This important core of CS education is now challenged, and at first sight maybe even obsolete by machine learning, because the problem-solving process dramatically shifts towards machine learning, in which the computer now fulfills the process of heuristic problem-solving by a process of trial and error. During this process, a model of the problem, which is also a model of the solution is developed by the computer, and the human problem solver/learner probably does not acquire a deep understanding of either the problem (analysis) or of the solution (design).

The machine learning problem-solving process changes the role of the human: Instead of analyzing the problem and designing a solution, the human collects example (in other words: data) of the problem together with possible solutions (in case of supervised learning): for example, picture analysis, e.g., number recognition, face recognition, object recognition in general, huge amounts of data are collected that show examples together with their solution. For example, pictures of handwritten digits, together with annotations what digit is seen. Or pictures of twins or chips, with a label. The role of the human is then to collect and label such data and feed it into the machine learning mechanism. This mechanism then develops a model for recognition that can be used to also recognize the elements in new examples. However, the human problem solver does not necessarily acquire deep knowledge about the problem. Instead, the model built by machine learning is a black box. This phenomenon leads to a shift also in CS research: e.g., accountability, explanations, or even a debate on new research areas (Rahwan et al. 2019).

DSE Relation to Math Education

In higher education, the scientific examination of DS methods and concepts requires, among other things, specific mathematical knowledge at the university level. As a result, most undergraduate curricula contain mathematical methods or are expected to be acquired by students in mathematics courses (Tang and Sae-Lim 2016). The main question here is not whether DS methods should be integrated into mathematical higher education, but which mathematical topics should be acquired within the framework of a DS course.

The situation is different in the area of secondary education, where DS is usually not an independent school subject. Here, among other things, there is also the question of whether parts of DSE can be integrated into mathematics teaching.

Many of the mathematics curricula have a similar structure to the NCTM curricula and are structured in terms of process and content dimensions. (NCTM 2019).

The process dimensions mostly include “problem-solving, reasoning and proof, communication, connections, representations.” Areas such as “Number and Operations, Algebra, Geometry, Measurement, Data Analysis, and Probability” are assigned to the content dimensions in many mathematics curricula.

In order to present a more precise correlation between DSE concepts and mathematical competence requirements, one would have to look at the curricula for the individual grades in detail. In the context of this entry, it is only possible to reveal potential links between elements of mathematics learning and teaching and DSE concepts on a general level. These arise both about the content and the process dimension of the mathematics standards.

For example, especially the contents from “Measurement,” “Data Analysis and Probability,” and “Number and Operations” are relevant for the adequate handling of data and DSE tools. In the data-oriented modeling of DS questions and the presentation of the results, almost all mathematical process dimensions are affected in different ways, depending on the specific problem.

It should be noted that, on the one hand, mathematical knowledge must be assumed in order to

use DSE methods and tools successfully. On the other hand, the use of DSE tools in mathematics teaching also opens up the possibility of acquiring and deepening mathematical knowledge.

In order to enable that kind of learning, some of the tools developed for school lessons (e.g., TinkerPlots, iNZight, see above) are already designed for use from fourth grade on, considering the mathematical knowledge available to the students. The tools are also suitable for further facilitating the students' mathematical understanding.

In connection with the use of DSE tools in math classes, the relation to computational thinking (CT) and the "big Ideas" of important computing principles also arise. Since, e.g., the handling of data and the presentation of the computing results illustrate the importance of computers and software tools also during math lessons, the students can thereby also acquire further competencies in the sense of CT (Wing 2006; Standards for Mathematical Practice 2019).

Some of them are: "Abstraction reduces information and detail to focus on concepts relevant to understanding and solving problems. Data and information facilitate the creation of knowledge"; "Algorithms are tools for developing and expressing solutions to computational problems"; "Programming is a creative process that produces computational artifacts"; "Digital devices, systems, and the networks that interconnect them enable and foster computational approaches to solving problems"; and "Computing enables innovation in other fields, including science, social science, humanities, arts, medicine, engineering, and business."

However, it should also be noted that the DS methods also concern contents and concepts in mathematics teaching that have not yet been genuinely the subject of mathematics teaching (Biehler and Schulte 2018). Although, for example, elements of stochastics, probability theory, and statistics can be the subject of mathematics lessons, further mathematical problems must be dealt with in connection with DSE topics:

"Problems of measurement (operationalization of variables, adequacy problem); Biases in sampling; Distinguishing observational studies from experimental studies; Random assignment and the

problem of confounding variables; Simpson's paradox; ecological fallacy; Confounding of conditional probabilities; Understanding visualizations of complex data (including interactive ones)" (Biehler and Schulte 2018).

Therefore, the successful implementation of DSE projects might require some modifications in traditional math curricula, especially in upper secondary education, considering the issues addressed above.

DSE Relation to STEM and Social Sciences

At the level of higher education, DS methods are used in many subjects, above all for empirical research but also in teaching, where DS methods can illustrate subject-related, empirically founded evidence. In this respect, at least the acquisition of basic knowledge of the methods of Data Science is envisaged in the curricula of many subjects, especially in economics, natural sciences, but also social sciences (De Veaux et al. 2017; Tang and Sae-Lim 2016).

At the level of secondary education in schools, DS methods are used to evaluate empirical data, particularly in the natural sciences and social sciences. In these school subjects, DS methods enable students to discover subject-related interrelationships. In STEM, DS methods can be applied, for example, to evaluate large amounts of sensor data and other publicly accessible more extensive collections of measurement data. In social science subjects, the publicly accessible data collections and statistics on social, geographical, economic, or political problems can be used similarly (see above, projects with Gapminder).

The students can achieve the necessary DS-related basic knowledge, mainly in computer science education and mathematics. The subject-related applications of DS-methods in the other subjects can contribute to deepening the students' DS knowledge they have acquired during math and informatics lessons. Therefore, on the one hand, it is necessary to coordinate the school curricula of the subjects concerned accordingly.

Since, on the other hand, DS-related content in the subjects of computer science and mathematics cannot be imparted without an application context

and particular content reference to areas of other school subjects, interdisciplinary cooperation and, if possible, the organization of interdisciplinary project teaching is always appropriate in DSE. Examples of such projects have already been described in the discussion of DSE project phases (see above).

Conclusion

The entry showed that data science and data science methods have become very important in many areas of society. In this respect, DS-related courses of study have been established in higher education and the further training of IT professionals. Furthermore, the anchoring of DS contents in the curricula can be observed even in courses of study that are not directly related to computer science or mathematics.

In the field of secondary education, there are several relations between Data Science Education, Computer Science Education, and Mathematics, especially in the field of Data Science methodology. Since the subject areas of the vast data collections and possible related evaluation tasks mostly also concern other school subjects, interdisciplinary cooperation is necessary.

For learning and teaching purposes in nearly all school subjects, various open source tools are available. These tools are suitable for students, partly already from grade 4. Through these tools and numerous extensive data collections, subject-related and comprehensive interdisciplinary Data Science projects can be realized in many subject areas of secondary education.

Cross-References

- [Artificial Intelligence in Education](#)
- [Competency Models in Computing Education](#)
- [Computational Thinking](#)
- [Curricula in Computer Science](#)
- [Data Mining for Educational Management](#)
- [Decision Support Systems and Knowledge Management in Education](#)

- [Educational Assessment, Educational Data Mining, and Learning Analytics](#)
- [Human, Social, and Ethical Aspects of Information Technology Management Systems](#)
- [Multimodal Learning Analytics](#)
- [Programming Languages for Secondary Schools, Python](#)

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Data Science Education Curricula

- [Data Science Education](#)

Deaf

- [Assisting People Who Are Deaf or Hard of Hearing Through Technology](#)

Debugging Programs

- [Programming and Coding in Secondary Schools](#)

Decision Making

- [Decision Support Systems and Knowledge Management in Education](#)

Decision Problems

- [Decision Support Systems and Knowledge Management in Education](#)

Decision Support Systems and Knowledge Management in Education

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Synonyms

[Data driven decision making](#); [Decision making](#); [Decision problems](#)

Definition

Decision support grew out of theories of organizational operation and improvement that encouraged the development of technical systems to help organizations act more rapidly and with more confidence. They did this by applying algorithms based on historical data and on curated resources – both data representation and documented organizational responses to similar data patterns in the past (knowledge codified for reuse). There is, therefore, symbiotic and reinforcing relationship between decision support and knowledge management. The operational success of current decisions is then fed back into the system to evaluate the efficacy of the underlying models.

Introduction

In a period in which large amounts of data from online educational solutions are readily available and analytical approaches are maturing, it is important to think about how to best leverage the results of emerging analysis. This is why one considers knowledge management in combination with decision support. Making evidence-based decisions is the core factor in continuous improvement, but decisions can only be made around the evidence base (the stock of knowledge) about what *can* work. More formal methods of organizational improvement (improvement science) rely on a mature infrastructure of managing and evaluating evidence (decision support) and accumulating and sharing information about what works (knowledge management). There are a growing number of examples of both school and higher education organizations building substantial technical capabilities to link evidence to action. What is particularly compelling is examples of large organizations making substantial changes to the way that work (student services, advising, instruction) is carried out and evaluated. We now have existence proofs that even the largest educational institutions can make substantial improvements and link those improvements back to their decision support systems. At the same time, decision support is moving beyond simple analysis of historical trend. We will see that in both administrative support systems and student-focused learning systems, predictive analytics are being leveraged to inform real-time responses to student behavior – with an underlying predictive warrant.

Recent History of Decision Support and Knowledge Management

There is a long history of the study of organizational decision-making, algorithms to support management decision-making, and the representation of analysis using graphics (Shim et al. 2002). It has been only in the last 15 years that large segments of the educational enterprise

have moved beyond old transactional systems to more integrated, enterprise-wide tools. This was a slow buildup of capacity. Narrowly focused student information systems were linked to human resources and counseling systems through new data standards (SIFA, PESC, etc.). Likewise, the large learning management systems ceased to be isolated data islands as new standards (e.g., LTI) for integrating more specialized personalized learning packages became mature. Behind all of this, increasingly modular infrastructure was also a growing level of maturity in data warehouse solutions and analytical tools that could help bring structure and apply statistical analysis.

What was missing was any depth of knowledge about what to do with this mountain of data. A number of firms (e.g., Knewton, Summit Learning, Class Dojo, etc.) have made claims of effectiveness, but there is little still limited evidence about how best to leverage these vast wells of data. Indeed, the evidence available suggests that the road to successful application of new decision support models must be supported by change solid management skills in organizational leadership. Georgia State is one of the most well-researched (if not well-understood) examples of a large university that has used effective decision support techniques and a collaborative approach to knowledge management to eliminate the correlation of race and ethnicity with graduation rates (BMGF 2015). A number of other institutions have adopted the software tools used by Georgia State, but no one has replicated the results. It's clear that the solution is not simply technical.

We can see similar dynamics driving much of the evolution of resource development in the US market (Alamuddin et al. 2016). In the K–12 sector, much of the past decade has been focused on developing clear standards for learning (Common Core) and more technical measures of school and educator effectiveness (test-based, growth models). This included a decade of work to improve the ability of student information systems to get the attribution of what adult(s) taught which subject to each student over any given

period. Before the latter part of the first decade of the new millennium, most school systems would not have been able to provide that attribution.

At the same time, one saw the rise of performance-based funding in public higher education – rewarding post-secondary institutions for student persistence, completion, and earnings post-completion. The demand on data systems and data quality that these policy shifts have required has been enormous. At the end of the first decade in the 2000s, very few states or districts could have accurately reported which students were taught what subjects by a particular teacher. K–12 student information systems were designed to ensure contract student-teacher ratios were maintained and class sizes were appropriate for the physical space allocated – not track teaching. Likewise, for higher education institutions, getting math and English placement correct and supporting struggling students to persist and complete did not matter financially, since all students' credit hours generated the same revenue for the institution. Those data simply weren't even tracked (remedial placement is still not tracked at the federal level).

The ability to track instruction (and other services) also made the creation of district and then statewide information systems possible. In the USA, many states received Statewide Longitudinal Data System grants to create the infrastructure to track student data from pre-kindergarten through graduate education. A number of states have extended that coverage to include early childcare, health, and employment data. What's still missing in most of these systems is any details about the adult practice associated with student outcomes. It is now possible to track that amount of math instruction, for example, a given student has received over the course of a year or even the series of courses a student took over a set of years – potentially including both secondary and post-secondary education. However, there is very little data available about the content of the course or the instructional practices used to support student learning.

At the student level, the widespread use of technology tools for education (learning games, learning management systems, personalized

tutoring systems, etc.) has also led to an explosion of micro-level data about student activity and outcomes at the individual quiz or game decision point level. While these data can be mined to create maps of students' abilities (as measured by these online assessments) and estimates of student engagement (using time stamps between actions), there is often little data that connect the individual student online work to practices or larger instructional intent in the classroom.

The history of knowledge management is much less developed during this period. If one considers the ongoing tension around competing definitions of knowledge management, it is not surprising that one does not see widespread acknowledgement of tools or practices in the education literature (or software offerings). One can see a thorough line between early efforts at knowledge management in education that have become more mature based on improvements in technology and supportive policies/investments. For example, a common knowledge management application for educators over the past 20 years has been the creation of resource repositories with associated metadata frameworks to support the location of resources that could be combined to create more sophisticated educational artifacts. In the USA, efforts such as the National Science Digital Library from the National Science Foundation or a number of curricular repositories created by private philanthropy were built around a “build it and they will come” strategy. MERLOT was an international effort from that period designed to make it possible to store, rate, and share educational resources. The Hewlett Foundation led efforts to build capacity across the sector to produce high-quality open-source resources. They did this through direct investments and by supporting the work of the Creative Commons. Staff from the Creative Commons began meeting with education officials across the USA in the early 2000s to support collective action between US education leaders. Serving as a digital repository is the most common form of knowledge management project in education. It is built around the notion that educators at all levels have little time to create unique curricular content

but do want to search for an assemble components across multiple collections to build hybrid materials for their courses. It is not clear how well such models align with the skills of most educators or the time they have available. There have been more concerted efforts in recent years to use open resources in post-secondary education to reduce the costs of materials for economically disadvantage students. Several states have partnered together to make resources searchable across multiple repositories. Again, these efforts suggest that location of resources is the primary goal. There are no aligned process or professional learning resources to support the adoption of new practices that are associated with more modern curricula.

The other common uses of knowledge management systems are only beginning to emerge in the education sector. Expertise location is a function that emerged early in professional service firms and in manufacturing. Given the isolation of classroom practice at all levels and lack of consensus on practice, it is not surprising that expertise location has not been widely used by formal institutions in education. However, both small and large technology companies are using individual teachers as brand spokespersons through social media (Singer 2017). Individual teachers are then compensated by these firms for opening their classrooms to share their personal practice in the use of technology tools.

Challenges and Benefits of Decision Support and Knowledge Management

The proliferation of tools available to support both classroom instruction and individualized practice and learning outside the classroom offers insights into instructional practice and learning on smaller and smaller time scales. The nearly ubiquitous use of learning management systems provides educators and administrators with outcome data on both low- and high-stake student assessment. Recent innovations from companies such as BrightBytes and Clever (Herold 2018) provide administrators and teachers with near real-time data on the use of

a range of learning tools so that not only outcomes are available to support decision-making but patterns of use as well. The broad availability of microdata on student outcomes holds the promise of supporting individualized student learning. However, the rewards of such systems remain elusive (Herold 2017) at scale, according to a series of studies conducted by the RAND Corp. The translation of what works in limited contexts to a set of broadly deployable set of solutions is the knowledge management challenge facing the sector. RAND study points to the challenges associated with designing and supporting a diverse set of student-facing resources. This highly sophisticated and demanding work requires that schools and districts allocate substantial resources to supporting time it takes to design, test, and share effective materials.

One of the primary limits to this work are the gaps in knowledge around what works for improving student outcomes across varied contexts. It is possible that broad-scale classroom experimentation could yield usable knowledge, given the widespread use of the tools described above, but the lack of alignment in standards for student learning and the wildly varying models for resource allocation, undercut the ability to answer the *what works* question.

The limits of the potential of the application of decision support and knowledge management are not technical. The ability to federate data across multiple systems and apply mature analytical frameworks are widely available. Knowledge management tools such as Google for Education, Box, DropBox, BaseCamp, etc. provide ample support for collaborative content creation and curation. Sophisticated support for metadata and search allows for easy discovery and sharing. The limits of the available tools are based on the norms and politics of the sector. Schools are still mostly organized as relatively autonomous instructors with little time for collaboration and led by administrators with too many direct reports to develop well. The incentives in most educational systems are still focused on student accountability as the primary driver instead of the communities obligation to deliver effective schools to students.

The Promise of Decision Support and Knowledge Management

Using big data from individualized learning applications to create predictive models for personalized support to tackle problems at the student level has enormous potential power (Agasisti and Bowers 2017). Using big data from historical records to build wrap around services to intervene outside the classroom (from community schools to Georgia Tech) and creating research-practice partnerships (or at least formal networks) to tackle persistent problems of practice could take advantage of the transparency provided by tools that allow use of federate outcome data across a heterogeneous set of learning technologies. Schools and support organizations (New Visions for New Schools, High Tech High, Rocketship, Summit, etc.) that have moved away from traditional organizational models and made continuous improvement a core part of their missions show that change is possible and that students furthest from success can achieve great outcomes.

Summary

While there is enormous potential in the education sector for the tight linkage of what is known with one's ability to use that knowledge in real time, the evidence base around efficacy is still quite thin. The promise of individualized learning seems to be something one must still anticipate.

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Deep Learning

- [Data Science Education](#)

Democracy

- [Digital Citizenship, A Sociocultural Snapshot](#)

Demographics

- [Learning Programming, Success Factors](#)

Dentistry

- [Indications for Kinesthetic Learning Through Haptic Devices](#)

Dependability in E-Assessment

- [Information Technology and Assessment](#)

Depository

► [Institutional Repositories Versus Learning Object Repositories, Challenges and the Way Forward for Higher Educational Institutions](#)

Design

► [Design in K-5 Programming Projects, Role of](#)

Design in K-5 Programming Projects, Role of

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Synonyms

[Algorithm](#); [Design](#); [Model](#); [Plan](#)

Design: Teaching programming is more than just teaching the syntax of a programming language, novices should be taught how to create programs, including how to design them (Soloway 1986). Design in K-5 programming projects is a creative process which takes an idea, task, or problem (a goal) and produces a design which can be implemented as code. The term design is both a verb (describing the process of creating a design) and a noun (the actual design artifact created).

The design artifact, for most young K-5 programmers, could be a remembered or recorded discussion about what they are going to make; an informal diagram, such as a storyboard, concept map, or labelled diagram; or a written note detailing their ideas. Some older learners might use flowcharts or pseudo code to more formally document their design. Within design artifacts algorithms are represented in a variety of simple

ways. The algorithm can be represented by an ordered set of photographs of a physical enactment of the planned program, the numbering of storyboard pictures to show the required sequence of events, or a written rule such as how a score in a quiz should work. (In simple terms, an algorithm is a set of steps or rules that make something happen or work something out.)

The process of creating a design used by learners will vary. Some learners will be aware of the path ahead; others will not. Some learners may design “on the hoof” with no thought of what will come next until they finish coding what they are currently attending to. Others may plan a few elements “ahead” before starting to code. Some might sketch out the whole of their solution in some detail before they start any coding. How young learners approach debugging, finding, and fixing errors in their code, will also vary, some will debug as they go along understanding they will code and debug each part in turn, evaluating and revising their design as they go along. Others might wait right until the end of their development.

Some learners will work “top-down” by creating and using a plan; others will explore and build “bottom-up.” Most are likely to use a mixed approach, sometimes thinking ahead, sometimes exploring and reacting to opportunities presented. Whichever approach is taken the underlying objective is for pupils to think, design, and learn by making a digital product (Kafai and Resnick 1996).

Programming Projects

Young pupils in K-5 education across the world are being introduced to the world of computing through learning to code. Early experiences include using programmable toys or simple programming languages with an initial focus on learning how to program simple sequences. As learners progress further, programming constructs such as loops, selection (if, then statements) are introduced as well as simple data structures such as variables and a variety of inputs and outputs including microphones and motors (K-12 Computer Science

Framework Steering Committee and Others 2016; Department Of Education 2013). Often educators create learning experiences to teach programming using projects to situate learning. Project goals could be suggested by teachers or pupils. It is likely that goals will include an audience, purpose, and genre of a task, as well as constraints such as the coding language (software) and hardware to be used. Genres of programming projects include route-based activities, puzzle-based scenarios, animations, quizzes, games, control (physical computing), and simulations and modelling.

Projects might include

“Make a James and the Giant Peach story mat for our programmable toys and make some route challenges for your class (don’t forget the answers too).”

“Using Scratch, create a simple animation of your favourite things for your next class teacher.”

“Using Logo, create a shape picture for a Celebration Card for your family.”

“Using Blockly, create a simple maths quiz for 6-year-olds to help them learn their doubles.”

“Using Kodu, create a game to help teach road safety for a national competition.”

“Using a Makey, Makey, Lego Wedo or Crumble Controller (or other physical device) make an interactive display about our current topic, Rainforests, for our family open day.”

How programming is taught varies. An approach favored by some is tightly scaffolded learning experiences giving pupils code to copy. Other strategies include solving predefined coding puzzles, using, modifying, and then creating new projects, remixing code, learning to read code before learning to write code, apprenticeship, guided exploration and tinkering (learning by exploration and trial and error). Several recent studies have suggested a combined approach of a range of strategies might be the most effective approach to teaching programming (Grover et al. 2015; Hansen et al. 2016). A blended approach might include targeted tasks that teach specific skills, including reading code and debugging tasks; live coding where the teacher demonstrates

design, coding, and evaluation; guided exploration where pupils explore a limited set of code blocks for a specific outcome; project work, including graduated support starting with pupils imitating good quality exemplar projects, then moving on to remixing, evolving, and changing example code to finally independently creating brand new inventions; as well as some copy code and tinkering if needed.

Whatever approach is used to teach programming, the role of design is not always clear, and there is limited research in this area. Notable exceptions to this include: investigations of the simplified Engineering Design Process with Kindergarten pupils learning about robotics (Bers 2017), a middle-school study of crafting and programming including creation of design artifacts (Kafai and Vasudevan 2015), and the introduction of the agile methodology (incorporating a design process) with high school students (Kastl and Romeike 2015; Missiroli et al. 2016). Despite some emerging research in design and programming for young learners, research related to design and computational thinking within classroom settings is even more sparse.

Design and Computational Thinking

Computational thinking has been suggested as the basic skill needed to learn to program. Proponents describe a variety of computational thinking concepts, approaches, practices, and techniques (The College Board 2017; Csizmadia et al. 2015). Concepts might include abstraction, decomposition, generalization (spotting patterns and using similarities), and algorithms. Approaches, practices, and techniques such as tinkering, creating, debugging, collaborating, persevering, reflecting, analysis, designing, and coding are suggested. Despite a lack of consensus of exactly what computational thinking is, and of its usefulness (Tedre and Denning 2016), abstraction is cited as being a cornerstone of computational thinking (Wing 2008). Abstraction has been defined as reducing unnecessary detail and generalizing solutions. In creating

designs, abstraction is needed, as the designer must decide what must be included and what can be ignored. Similarly, as the designer breaks the problem down into parts, they are decomposing their solution. In detailing parts of the design algorithms are included. This might be in the form of the ordering of action, or in defining the rules to be implemented. If storyboarding an animation, the order of events is the algorithm. If designing a quiz or game, a written rule for maintaining a score is an algorithm. When designing a project to have reusable components pupils show they can generalize. For example, if designing a program to create a shape picture, learners might include the idea of a generic shape drawer, which uses the number of sides of a shape to draw any shape, rather than having separate, distinct components to draw each different part.

The relationship between design and computational thinking has not yet been fully explored, and research is very limited in this area. However, there is much research related to planning in other subjects that could inform pedagogy associated with teaching design in programming.

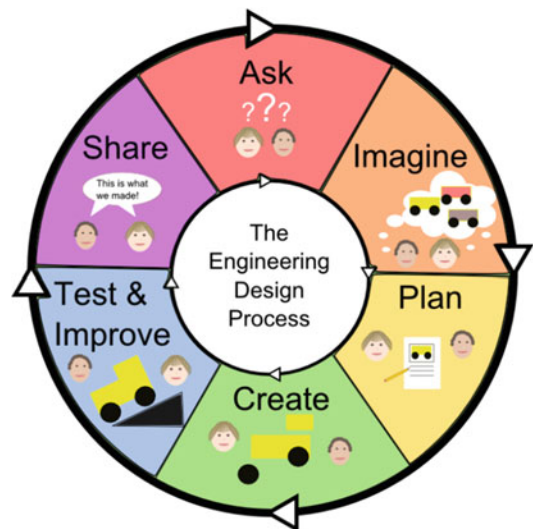
Planning in Other Subjects

In other school subjects, some teachers request that pupils plan their ideas for a substantial piece of work. For example, in story writing storyboards might be used to provide an overview of the key events to be included. In creating a history report a concept map might be used to highlight key themes. In design and technology lessons labelled diagrams provide an overview of the product to be made. In dance a choreography can be developed through a series of stick figure drawings. The plan separates the process of gathering and evaluating ideas from the process of implementing these ideas in the finished project. Once created the plan provides an aide-mémoire of what is to be done, allowing pupils to self-manage the implementation phase and supporting independence. Research in learning to read and write indicates that setting goals, planning and understanding a process for

accomplishing tasks leads to improvements in self-efficacy, self-regulation, and progression in learning (Dockrell et al. 2015; Graham and Perin 2007; Schunk and Swartz 1993; Tracy et al. 2009; Whitebread and Basilio 2012).

Processes and design artifacts used in Design and Technology lessons such as following an Engineering Design Process and using exploded labelled diagrams can be particularly useful for programming projects which incorporate physical computing. Teaching coding with robotics and tangible programming languages in kindergarten, the research team at Tufts University have developed curriculum materials and a simplified Engineering Design Process of ask, imagine, plan, create, test, and improve and share (Bers et al. 2014) as shown in Fig. 1.

There may be opportunities to use familiar cross-curricular planning tools from a range of subjects in programming projects as design tools. However, research on what design might look like in K-5 programming projects is limited as is pedagogy on how it should be taught (Waite 2017).



Design in K-5 Programming Projects, Role of, Fig. 1 A simplified engineering design process from Tufts University's programming and robotics curriculum unit (2010). (<http://ase.tufts.edu/devtech/tangible/Classroom%20Curriculum%20Version%201.02%20Nov%208%202010.pdf>. © DevTech Research Group, Tufts University)

Levels of Abstraction

A levels of abstraction framework has been suggested to support investigation of university students’ understanding of algorithms and learning to program (Armoni 2013; Perrenet et al. 2005). Studies using this framework indicate that students work mostly at the coding and running the code level and suggest that if learners knew what level they were working at and could more effectively transition across all levels, they may be more successful in their programming endeavors. A K-5 version of the framework, as shown in Fig. 2, has been used in exploratory research with younger learners and their teachers (Waite et al. 2016).

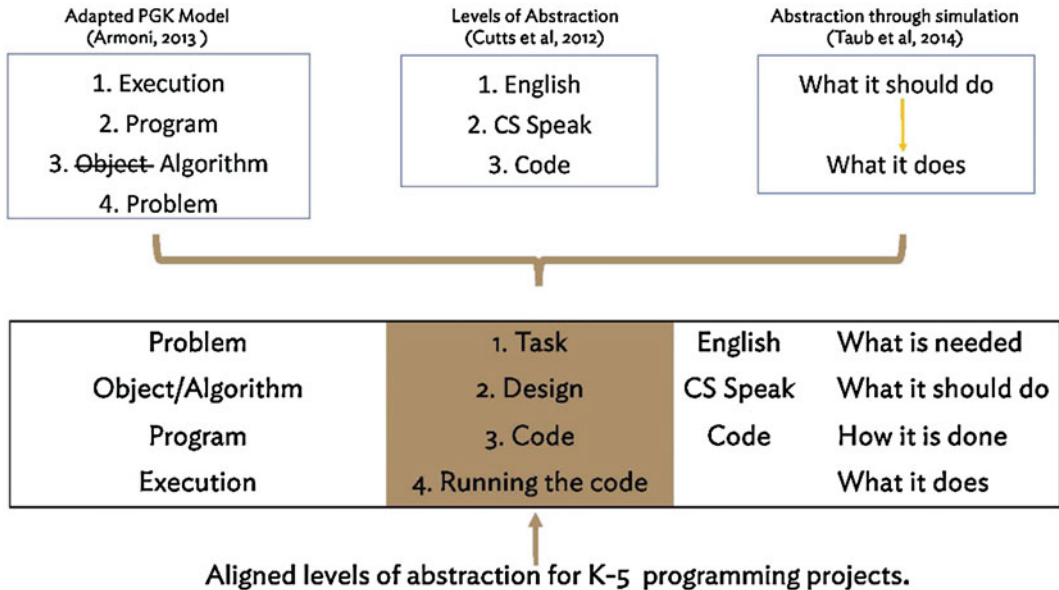
In aligning the framework to a K-5 setting several assumptions and caveats are made to support K-5 teachers. First it is assumed K-5 teachers and their pupils have less expertise in program development than those educators for whom the original frameworks relate, therefore more familiar terms have been introduced for each level. For K-5 projects, the design level also includes user interface design, algorithm, and data structure

design. It is not expected that K-5 pupils or teachers will formally distinguish between these components in the same way that specialist computer science educators teaching older pupils might. Similarly, the boundary between the original frameworks’ problem level and the object level compared to the boundary between the K-5 task and design level is much simplified. For example, any analysis associated with requirements might traditionally sit in problem level definition for older learners; however, for younger pupils a simple task definition of a few sentences is suggested with all further analysis and design being encompassed in the design level.

Uses of Design Using the Level of Abstraction Framework

In exploratory research on uses of levels of abstraction, particularly the design level, in K-5 programming projects (Waite et al. 2017) there is indication that there may be opportunities to use design.

As an aide-mémoire to know what to code next



Design in K-5 Programming Projects, Role of, Fig. 2 Aligned levels of abstraction for K-5 programming projects. (Waite et al. 2016)

To differentiate work, by teachers annotating the design with challenges or hints and tips (such as useful code snippets)

To scaffold implementing the design as code, by pupils and teachers annotating the design with code snippets

As a contract between pupils when pair programming

As an assessment tool for pupils, by pupils self-assessing their confidence to code elements of the design

As an assessment tool for teachers, by teachers reviewing pupils' understanding of how to create and implement designs

For teachers to see what they might need to teach

To evaluate completeness and coherence of the proposed solution

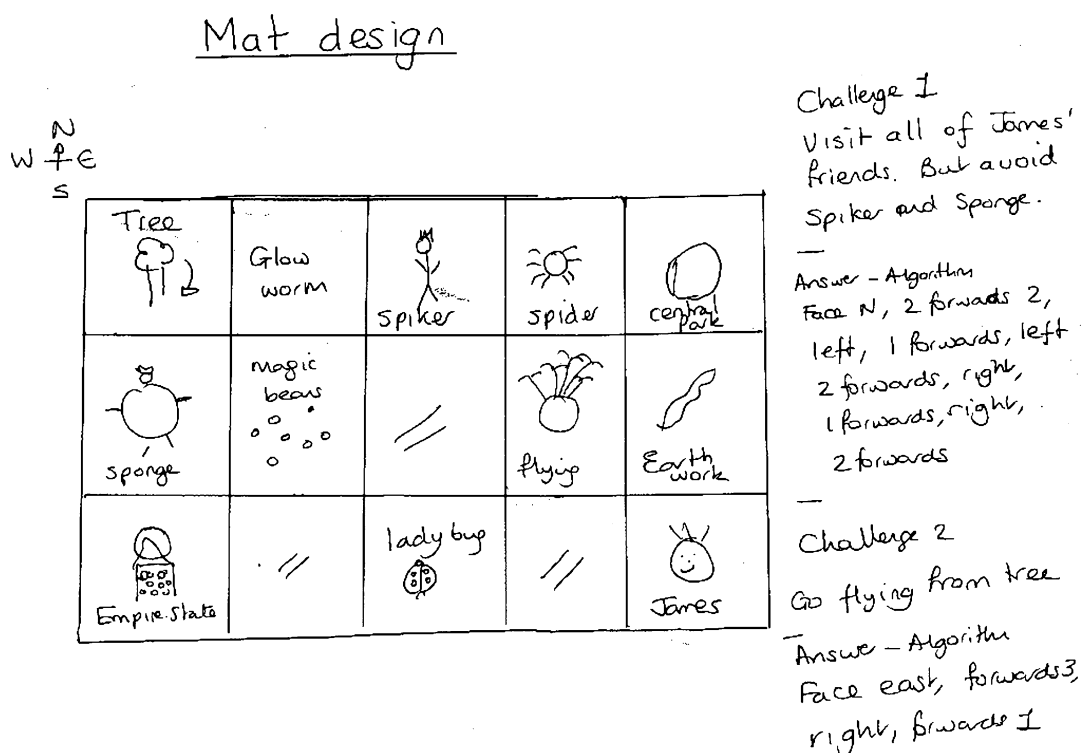
In annotating designs with code snippets, learners are transitioning between the design and code level. Similarly, by working with a physical design artifact learners' attention is drawn to this

level of abstraction as they are overtly working at the design level.

Research is ongoing to discover whether early results are generalizable across a wider population of teachers. However, based on initial findings it seems that some teachers are using design in novel and interesting ways to support pupils learning to program.

A Simple Mat Design

Figure 3 shows an example design for the task "Make a James and the Giant Peach story mat for our programmable toys and some route challenges for your friends (don't forget the answers too)." Young pupils might have their challenges recorded as sound clips or scribed by adults. In recalling the settings and characters to make the mat they are consolidating their literacy work in computing lessons. The teacher might demonstrate how to create a mat and show how to



**Design in K-5
Programming Projects,
Role of, Fig. 4** Simple
animation design example

Date: 27/8/2017

Design for My favorite things

Name: Miss Waile

Task: Make an animation of my favorite things

me

Hat.

pizza

cat

Draw background, add labelled characters

Animation		
move to pizza	Cat runs about	Jump up and down
Record I love hats.		

include just a sketch of each image, explaining that lots of detail is not needed. This is an example of modelling abstraction. She also might model changing her ideas as she starts the creation of the actual mat, showing that design can change. By including an “avoid” or “spin on” requirement in an example challenge she can show how to make a more complex solution algorithm and how to decompose a route into parts.

Using Labelled Diagrams and Storyboards for Designs

For the task “Using Scratch, create a simple animation of your favourite things for your next class

teacher” a labelled diagram and storyboard has been used for the design, as shown in Fig. 4. The labelled diagram shows the main characters and gives opportunity to discuss what will be a sprite and what will be the background. The storyboard shows the animation over time. The teacher can demonstrate how to annotate the labelled diagram with the word “sprite” for each of the objects she chooses to be a sprite and discuss meaningful names for each sprite. Similarly, she can ask pupils to add the commands they think they might need to code the design. She can differentiate work by annotating the design with code snippets for those pupils who need extra help. For self-assessment pupils can add an indication of their confidence to implement each code

snippet, for example by highlighting with a red, yellow, or green pen. The teacher can then review the annotations and see what needs to be taught.

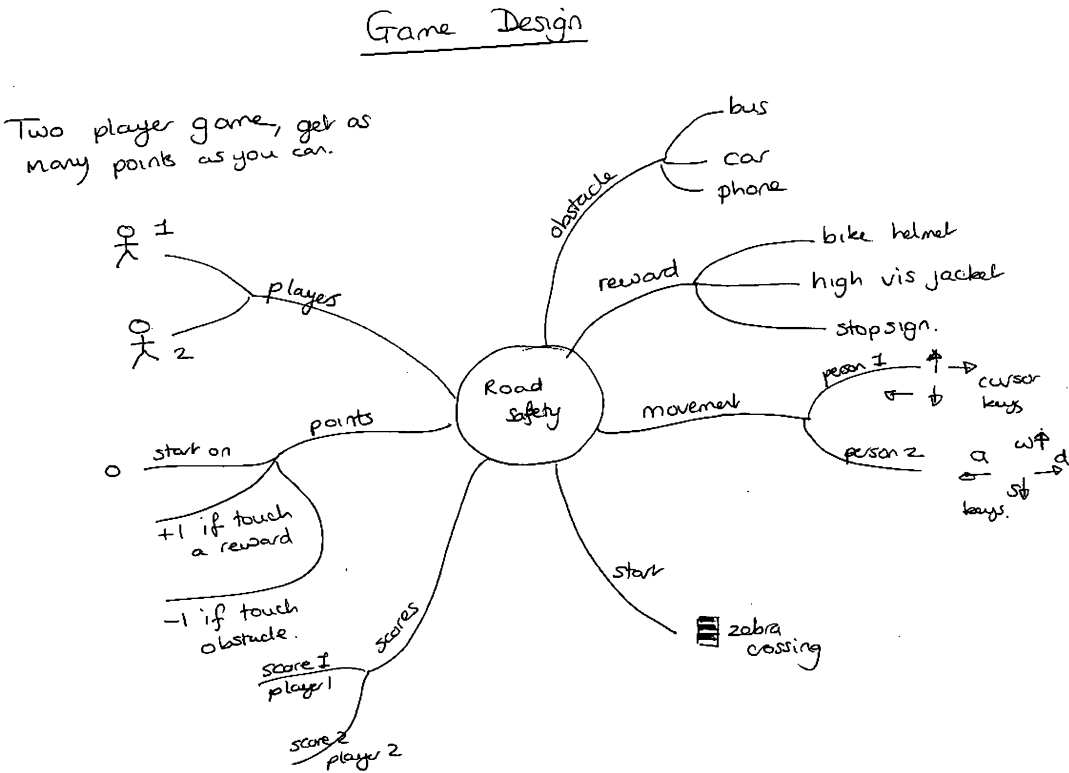
Using Concept Maps for Designs

As shown in Fig. 5, a concept map has been used for the design of the task “Using Scratch, create a game to help teach road safety for a national competition.” Different design types may be more suited to a genre of programming projects. For example, games often have rules that persist over time, such as how to control the movement of characters or how to keep score. Concept maps may be more suited to projects with rule-based algorithms or for learning scenarios requiring easy addition of extra detail as the projects develop. For example, learners who prefer to create programs “bottom-up,” that is exploring and building a solution through re-mixing and bricolage, need a design artifact that can grow and change with their

ideas. Similarly, learners who like to investigate each aspect of their program in much detail before moving onto the next may prefer concept maps, as these are not constrained by the size of a story-board box.

To differentiate the process of design the degree and type of support offered to learners can be varied. The teacher can provide most support by working with a group of pupils to create a team design artifact. She can provide a precreated design for other pupils to remix and amend and ask the more confident to work in pairs. Similarly, as the design is then used to support a move to coding, she can ask more experienced learners to peer assess other pupils’ code annotations and provide help cards of common code patterns.

The teacher might mark designs and further differentiate work by adding extensions, such as requesting the addition of inputs and outputs such as using a Makey Makey. When modelling using the design to support coding, the teacher might show how to tick off items implemented, and how



Design in K-5 Programming Projects, Role of, Fig. 5 Game design example

to debug as coding progresses, showing how to choose what to implement next. For example, implementing all the code for one player before adding the second player code and thereby learning from this first pass. Targeted tasks might be used to teach how to create and use designs, such as spot the difference on example designs, completing partially made designs, matching example designs to code, matching designs to tasks, comparing different annotations of code snippets for the same design, debugging designs, quick coding activities from partial designs, reverse engineering designs from code.

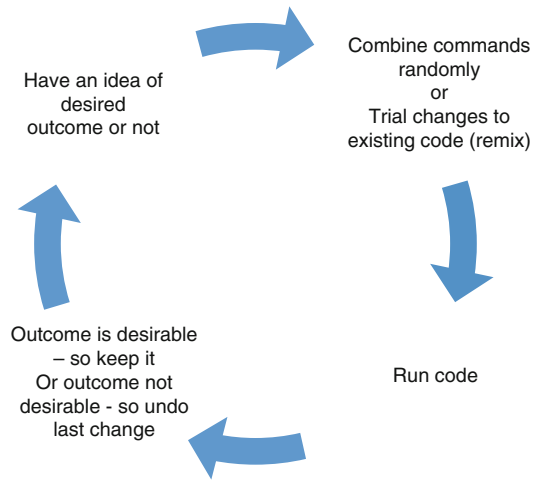
Drawbacks of Using Design

There are potential drawbacks from using design in K-5 programming projects. A significant risk relates to motivation and pupils' expectations of the process of programming. Some pupils may expect to start coding as soon as they are presented with a programming activity. These learners could feel demotivated and frustrated if they are required to "slow down," think ahead and create a design before they code.

Another issue might be that if pupils are asked to invest time on a detailed design, they may then be reluctant to change and develop their ideas. This can stifle creativity.

Some learners favor a bricolage approach (Turkle and Papert 1990) when creating programs, using personal experience of trial and error, tinkering, to explore what commands do, and develop an understanding of what might be achieved. In this "bottom-up" approach, as shown in Fig. 6, some programmers will have a conscious idea of what they want to make, others will not, but both can benefit from serendipitous discoveries. There is risk that design might stifle such playful engagement, reduce assimilating and accommodating experiences and constrain development of logical reasoning skills. Using design may suit learners who favor a "top-down" planning approach rather than "bottom-up" working.

However, there appears to be evidence that novice and expert programmers may take a mixed approach, switching between "top-down"



Design in K-5 Programming Projects, Role of,
Fig. 6 A 'bottom-up', bricolage or tinkering approach to programming

and "bottom-up" as and when needed. In this mixed scenario programmers sometimes plan, consciously designing and thinking ahead, and at other times explore and tinker. They switch between approaches based on their knowledge of the problem in hand, experience in the programming language, and confidence level. Which design processes and design artifacts are best suited to "top-down," "bottom-up" and mixed approaches in K-5 programming projects is, as might be expected, something that requires further research.

Comparing Industry Practice to Learning to Program in School

When designing, requirements are considered, constraints accounted for, ideas are generated, alternative options evaluated and choices made. In commercial computing scenarios, a wide range of requirements are fed into the design process including user requirements, audit and regulatory standards, program performance, system maintenance, and future needs. When first learning to design, younger learners will focus on a much-simplified subset of requirements. K-5 pupils will focus on the purpose of the thing to be created and the needs of the person who will be using their

finished product. Some learners might also consider criteria related to user interface design, how easy it is for others to understand their design, reuse of components and ease of change of their design, and even algorithm efficiency.

In professional IT projects, hundreds of developers might work on projects spanning years with vast amounts of money being spent on producing complex products such as banking systems and automated factories. In school settings K-5 learners might work independently, in pairs or small groups. Competing for precious teaching time, in a packed curriculum, these projects are likely to be completed in 4 to 6 hours over a 6-week school half-term.

Methodologies have been developed to manage commercial projects. Notable examples include the waterfall method and the agile methodology. Very simply put, the waterfall methodology requires the design for the whole project to be considered before coding starts whereas in the agile methodology the project is broken down into parts, where each part is designed, coded, and implemented before moving on to the next part (Cockburn 2002). The process young learners follow to manage their project is not likely to be the same as that used in industry, as pupils are learning about programming and design as well as using design to create a program. They are developing competencies through a design learning path, which incorporates exploration as well as design (Schulte et al. 2017). Stages in a design learning path can include asking questions, collecting ideas, exploration, decomposition, documentation, discussion, developing underlying skills, sharing, and points for self-assessment. Teachers might explicitly demonstrate the process of design and create exemplar design artifacts. They could include targeted tasks to scaffold learners' progression in design, or teachers may allow learners to develop their understanding of the process of design and design artifacts through exploration and tinkering.

In commercial projects, the design artifacts created vary according to the methodology used. Project management software is likely to be used with formal models of requirements, processes, and data structures being created. For young

learners, the design artifacts will be far less formal and may be verbal, written, or drawn.

Irrespective of what design process is followed, and what artifacts are created, design transitions the programmers' understanding of the task to a level of understanding at which they can write code. A physical design artifact, such as a storyboard or concept map, provides a route map and aide-mémoire, for a young programmer. It decomposes the design into meaningful chunks that novices can use to scaffold the process of converting this understanding into code.

Conclusion

Design in K-5 programming projects is the process of creating an understanding of a goal such that the young developer can implement that understanding as code. Some learners will follow a design process, where they think ahead, perhaps designing the whole of the product they intend to make before starting to code. Others may think to design a few parts at a time, and some may work serendipitously, evolving code as they explore with no attention to design. Typically, processes are either "top-down," creating and using a plan, or "bottom-up," exploring and building from the code. It is likely that most novice programmers will use a mixed approach, switching between "top-down" and "bottom-up" as they have ideas, work on one part at a time, learn about the task and software being used, explore, and try things out.

In primary school settings, the design process is often happening inadvertently and is likely not to be written down or retained. Design can be facilitated through an ongoing thought process which is not articulated or recorded in any way, through a physical unplugged activity acting out an event or process, or through a transient discussion. Where design is explicitly considered it is likely to be facilitated through creating drawings and written notes. Design artifacts such as storyboards, concept maps, and labelled diagrams can be developed and used. Within the design artifact, algorithms, steps, or rules that work things out or make things happen, may be depicted. Algorithms might be represented by the

simple numbering of events, a jotted rule, or even a flowchart.

Design is likely to be encountered by K-5 pupils when they tackle programming projects. Within the timeframe of the project, learning through and about design may be accomplished through a range of activities. What strategies and techniques teachers are using to teach such projects, and what approaches are most effective is not clear. However, several studies have suggested that a blended learning approach might be effective in teaching programming. Blended learning includes targeted tasks such as reading and debugging activities, teacher demonstrations, guided exploration, tinkering, using and remixing programs, creating new projects, and incorporating computational thinking.

Despite a lack of research into the use of design in primary programming, using planning to help emergent and struggling writers to learn to write has a long history of investigation that evidences the positive impact planning has on pupil self-efficacy, self-regulation, and quality of work. Common writing planning techniques such as creating and using storyboards, concept maps, and labelled diagrams may provide familiar tools for primary teachers to start to incorporate design in programming projects. Similarly, the Engineering Design

Process, used by some teachers when teaching Design and Technology, provides a “top-down” ready-made design process which has been incorporated as a simplified version in some robotics and programming curricula.

Educators make choices when creating primary programming learning activities, including choosing the objectives to be learned, expected pupil progression, differentiation techniques, assessment approaches, type of pupil involvement, hardware and software to be used, learning frameworks and models, teaching strategies and techniques, the genre of the activity, the design process, and whether design artifacts will be used. Figure 7 shows a subset of these choices that are particularly pertinent to the role of design in programming.

A learning framework that is particularly significant for the teaching of programming is the K-5 levels of abstraction framework (task; design; code and running the code). It has been proposed that if learners know what level they are working at, and if they can transition between the levels, they may make more progress in programming. Early research into the use of the levels of abstraction framework with primary teachers indicates that teachers are using levels, particularly the design level, in novel and interesting ways. By

Learning frameworks and models	Teaching Strategies & Techniques	Activity Genre	Design Process	Design Artefacts/ Tools
• Levels of abstraction • Task • Design/ Algorithm • Code • Running the code • Computational Thinking Concepts • Abstraction • Decomposition • Algorithms • Pattern/ Generalisation • Logical Reasoning • Evaluation • Computational Thinking Approaches • Creating (Designing & Making) • Debugging • Collaborating • Persevering	• Copy code • Targeted tasks • Reading code and predicting what it will do or what it achieves • Debugging activities • Comparison activities • Unplugged/physical activities • Teacher demonstration • Guided exploration • Projects • Use/Play/Read • Imitate • Modify/Innovate • Create/Invent • Tinkering • Blended • Use Modify Create	• Route or puzzle based • Animation • Quiz • Game • Simulation • Control • Mixed	• Bottom-up • Tinkering/ Bricolage • Top-down • Simplified Engineering Design Process • Mixed • Industry methodologies • Agile • Waterfall	• Storyboards • Concept Maps • Labelled Diagrams • Flowcharts • Pseudo code • Written notes

Design in K-5 Programming Projects, Role of, Fig. 7 Aspects of design in K-5 programming activities

annotating designs with code snippets, learners are being scaffolded to move between the design and code level. Also, using a physical design artifact draws learners' attention to the level they are working at. The design artifact is also being used as a contract for pair programming as well as by teachers to know what needs to be taught next. Design annotations are also being used to differentiate work, and the design artifact is also used for pupil assessment and self-assessment. Perhaps most importantly design artifacts are being used to gather ideas and act as an aide-mémoire during implementation of those ideas to support learners' independence and self-regulation much in the same way that planning is used to support primary classroom writing.

There appear to be opportunities to build upon teachers' expertise and pupils' experience of "planning to write" in "designing to program." However, what design process and design artifacts are currently being used in classroom programming lessons is not clear. Similarly, research on pedagogy for teaching design in programming projects is limited and requires extension to younger pupils in classroom settings, and most importantly further research is needed to discover the effectiveness and impact of including design in K-5 programming.

Cross-References

- [Computational Thinking](#)
- [Programming](#)

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Design of Online Assessments

- [Designing Assessments for Blended Learning Scenarios](#)

Design Pattern

- [Teaching Software Design Techniques in University Courses](#)

Designing Assessments for Blended Learning Scenarios

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Synonyms

[Design of online assessments](#); [Electronic assessment design](#)

Introduction

This entry examines the design process required for developing assessments within blended learning scenarios. Furthermore, it examines how practitioners in higher education can be supported to develop their understanding of assessment and how to design assessments into their teaching. The focus is specifically on blended learning scenarios where the expectation is that learning will be achieved through a mix of face-to-face and online interaction. However, as blended learning is a relatively broad term that may incorporate situations that are predominantly face-to-face or predominantly online, many of the principles will also apply across a broad range of learning situations. The entry draws on findings from analyzing the needs of students and lecturers and common issues relating to access to online educational resources across a partnership of Indian and European universities involved in the EQUAL Project (E-QUAL Enhancing Quality, A.a.G.o.U.E.i.I 2017). The project addressed a range of subject areas to develop design processes and

implement teaching and learning resources and activities for use in various blended learning scenarios (Webb et al. 2017). One benefit of drawing on this project is that the considerations in this study ranged across needs of students from different backgrounds and contexts as well as institutions with different infrastructure provisions. Therefore, our analysis has fairly broad considerations and applications.

In this entry, first the terminology is outlined and then important perspectives on assessment, in relation to the needs of blended learning scenarios are analysed. Then considerations are examined regarding who or what is the assessor: the teacher, the student, their peers, or technology. A brief overview of possible influences of changing assessment practices in higher education is provided. Next, the assessment design considerations identified as being essential for blended learning scenarios are outlined by examining the potential use of the revised Bloom’s taxonomy (Anderson et al. 2001) incorporated into a decision support tool to assist teachers in thinking about designing assessments (Webb et al. 2017). Finally, teachers’ professional development needs and challenges in relation to designing assessments in situations where electronic and/or online opportunities are increasing are discussed.

Terminology of Assessment

Although formative and summative assessment are commonly used terms in higher education, our experience suggests that these and other related terms have varying meanings in different contexts and confusion remains. Therefore, first, the terms are define used here are defined the issues that may inhibit effective debate in this area outlined. The term assessment itself is relatively unambiguous in that it refers to the checking of someone’s knowledge, understanding, skills, or capabilities. However, this same term is applied both to the process of checking and to the outcome of this process. Furthermore, in some educational circles, the term evaluation is used in place of assessment. In this entry evaluation is used as a broader term relating to understanding the overall

successes and failures of a course or program rather than for assessing students.

Four perspectives on assessment have been identified as shown in the model presented in Table 1 (Webb et al. 2013). This model distinguishes between a focus on the assessment process and on the results of the assessment. Furthermore, the model refers to “assessment for learning” and “assessment of learning” (Assessment Reform Group, A 2002). These terms have been used in various educational circles, in place of formative assessment and summative assessment, respectively, in order to emphasize the purpose of assessment and its relationship with learning.

Referring to Table 1, Perspective 1 is about students learning from feedback discussions and information provided during an assessment process. Perspective 2 focuses on using results of assessment for adapting teaching and learning processes. The third perspective is about the extent to which students understand the assessment process and are able and willing to engage with it. This perspective reminds us that ensuring that our assessments are accurate reflections of students’ achievements is by no means straightforward. The need to understand what will be assessed and how the assessments will be conducted becomes particularly significant when students are learning not only from the materials and teaching sessions that lecturers provide but from a broad range of online opportunities not necessarily recommended by the lecturers, for example, MOOCs that have become a significant and controversial issue in higher education provision (see, e.g., Zheng et al. 2018). Perspectives 1,

Designing Assessments for Blended Learning Scenarios, Table 1 Four ways to think about assessment (Webb et al. 2013)

	PROCESS focus	RESULTS focus
Assessment Flearning	Perspective 1 Feedback discussions and information	Perspective 2 Improvement decisions
Assessment OF learning	Perspective 3 Degree of engagement with/understanding of process	Perspective 4 Value judgments

2, and 3 are all key elements of formative assessment, which, by definition, supports students' learning and may be carried out by teachers, peers, and/or students on themselves (self-assessment). Perspective 3 is important both for formative and summative assessment because, in order to generate valid assessment information, students need to understand the assessment process and engage with it. Perspective 4 is about making summative judgments for purposes of grading and accreditation. Clearly such judgments are important and necessary at transition points between elements of a program of study and at the end.

Historically, evidence suggests that students fail to attend to feedback comments when given grades (Butler 1988) and confusion regarding the utility and need for feedback remains today. For example, despite evidence of students preferring written feedback together with annotated assignments providing explicit detail (Giles et al. 2013), studies have also shown that students do not always identify formative feedback as relevant (see, e.g., Douglas et al. 2016). Furthermore, students may not act on feedback owing to insufficient background knowledge or because the approach to feedback fails to take account of affective elements of learning (Sadler 2010). Thus, feedback involves complex processes that may be facilitated by considering not only the nature of the material and assessment but also how to engage learners in the assessment and feedback processes.

Assessors: Teacher, Self, Peer, and Technology

When designing assessments, in addition to considering the four perspectives outlined above, it is necessary to consider who/what is conducting and/or managing the assessment: students themselves, their peers, the teacher, or technology in an automated system. Enabling students to self-assess is an important goal of education because self-assessment supports the potential for students to become independent learners and to learn efficiently from the wide range of opportunities

available including online materials and activities. The ability to self-assess is also necessary for self-regulated learning (SRL). SRL, a psychological construct, refers to an active, constructive process in which students intentionally set learning goals and then plan, monitor, and regulate their cognitive, behavioral, emotional, and motivational processes in the service of those goals in order to achieve optimal learning (Pintrich 2004). The evidence suggests that one of the best ways of developing students' ability to self-assess is through peer assessment (see, e.g., Black et al. 2003).

The process of peer assessment is most productive, as well as most acceptable to teachers and students, when it involves students assessing each other's work against specified criteria and providing feedback to each other, rather than trying to assign grades (Liu and Carless 2006). For peer assessment to be a formative assessment process, the feedback needs to focus on what the student has achieved and what they should do to improve their work, together with some ideas about how to go about this improvement (Black et al. 2003). In formative feedback, dialogue forms the mechanism by which a learner monitors, identifies, and then is able to "bridge" the gap in the learning process (see, e.g., Webb 2010; Black 2015). Therefore, effective peer assessment processes become dialogic processes between students. Just as with self-assessment, discussed above, a close relationship exists between good quality peer assessment processes and self-regulated learning. The peer interaction provides opportunities for co-regulation of learning or socially regulated learning (Grau and Whitebread 2012) in which students support each other in regulating their learning.

There is also a developing body of research in support of peer assessment as a summative assessment process. There is evidence that in some fields peer assessment is just as reliable as tutor assessment (Li et al. 2016). However, the reliability and acceptability of summative peer assessment depend on the particular discipline and the credibility and capability of the person giving feedback. Furthermore, peer assessment can meet resistance from both tutors and students (Liu and Carless 2006) because in many

institutions, the expectation is for teachers to teach and make judgments about students.

Changes in Assessment Practices

More generally, assessment practices in higher education have been changing and diversifying for some years. New approaches are emerging, based on developments in digital technologies, which are increasing the range of possibilities for assessments, including increasing opportunities for personalization of assessments (Yeh 2010) and the capability for assessment to measure a broader range of knowledge and knowledge in action (Clarke and Dede 2010). For example, students can be assessed through simulations, e-portfolios, and interactive games (Gibson et al. 2007) rather than end of term exams and essays. Evidence is compelling that the nature and form of assessment have a significant impact upon the student learning experience, approaches to learning, motivation, and retention rates (Ridgway et al. 2004).

In higher education, the nature of an institution often dictates how assessment practices have been developed. For example, open and distance learning environments have emphasized the necessity for formative assessment practices. Distance education in general has been proactive in formative assessment practices out of the need to find ways to provide systematic feedback and direction to students in the absence of the immediate contact and interaction that students have enjoyed with tutors in a campus setting (Hatzipanagos and Warburton 2009). However, in both types of environments, the impact of assessment on learning can be moderated by the use of appropriate assessment methods by teaching practitioners, and practices have been supported/complemented by the use of computer-assisted learning resources (Guri-Rosenblit 2005).

Practical Considerations in Designing Assessments

Online assessments require good Internet connections, and infrastructure issues in developing

countries such as India may render online assessments unfeasible in the short term (Webb et al. 2017). Therefore, consideration needs to be given to computer-based assessments that could be delivered off-line or within a local intranet. However, our expectations are that such technical problems may be resolved within a reasonable timescale and therefore institutions also need to look ahead to consider future options.

There are also a range of tools and systems that can be used to implement assessment designs. These may range from objective testing platforms (e.g., exam-builders, Questionmark, Moodle quiz, learning management systems, assessment tools, etc.) to e-portfolios tools (e.g., Mahara, PebblePad, etc.) to authoring tools (e.g., word processors, HTML5, Storyline, etc.).

Thus, assessment decisions may be influenced by or limited by infrastructure considerations and availability of technologies or knowledge about applicability of such technologies. With this wide range of opportunities becoming available, it is especially important for assessment designs to be considered as part of pedagogical designs.

Assessment Design Within an Overall Pedagogical Design

For assessment practices to be effective in relation to the four perspectives outlined above, their place in the overall pedagogical design needs to be clear. Our view, in line with Black's (Black 2015) five-stage model of assessment in pedagogy, is that assessment considerations and actions need to be integrated in all aspects of pedagogy so that there is a match between the aims and the specific learning outcomes and the activities to support the aims and the methods of assessment. In particular, in relation to designing online materials, design of assessment must be incorporated from the initial stages of the design process just as when a teacher is planning a face-to-face lesson, the learning outcomes, activities, and assessments need to be designed to be closely aligned (Black 2015). Design decisions include the purposes of the assessment; consideration of whether the assessment is self, peer, teacher, or

Designing Assessments for Blended Learning Scenarios, Table 2 The taxonomy table (Anderson et al. 2001)

The cognitive process dimension						
The knowledge dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual knowledge						
Conceptual knowledge						
Procedural knowledge						
Metacognitive knowledge						

automated process; practical and educational considerations regarding the mode of delivery and particular technologies to be used if appropriate; as well as what knowledge and skills are to be assessed.

A Framework for Design Considerations

Designing assessments can be supported by a framework to encourage thinking and discussion in relation to specifying learning outcomes (LOs) and designing associating learning activities assessments. A revised version (Anderson et al. 2001) of Bloom’s taxonomy of educational objectives (Bloom et al. 1956) provides a useful framework for considering learning outcomes and how to assess them. Bloom’s taxonomy was originally developed to facilitate sharing of test items between university faculties. The revised version (Anderson et al. 2001) takes account of advances in cognitive psychology and other developments since the original taxonomy was published. Whereas Bloom’s original taxonomy is arranged as a one-dimensional hierarchy with a built-in expectation of progression between levels, the revised framework is two-dimensional. There is still an indication of a hierarchy, but it is acknowledged that categories overlap and the constraint of the “cumulative hierarchy” has been removed (Anderson 2005). The taxonomy is generally represented as a table (see Table 2).

The intention is that any learning outcome can be characterized in terms of both knowledge and cognitive processes and thus can be categorized into one of the cells in the table. Using the table to examine alignment between learning outcomes, instructional activities and assessments are a key aim of the development of the taxonomy (Anderson 2005).

Based on theoretical, pedagogical, and practical considerations outlined earlier in this entry, Webb et al. (2017) developed a framework to support considerations for designing assessments. The framework was based on the revised Bloom’s taxonomy and also incorporated technical considerations, consideration of the purpose of the assessment: whether formative or summative, the assessor (peer, teacher, self, computer) and examples of appropriate assessment activities (see Table 3).

Enabling Practitioners to Design Assessments

As explained above, considerations for designing assessments include:

- The type of learning outcomes that can be considered using the revised Bloom’s taxonomy
- Who is to assess – whether peer, teacher, self, or technology
- The purpose of assessment, i.e., formative or summative
- Technical considerations such as infrastructure requirements
- Whether suitable computer-based tools are available and the particular advantages of each type of tool

Thus, the range of possible approaches and their advantages and limitations exist in a complex decision space. While teachers, rather than IT developers, are best placed to understand assessment requirements and student needs, it is challenging for teachers to be aware of the range of possibilities as well as the consequences of their

contain a set of rules about the relative advantages and limitations of various different approaches to assessment and the outcomes of using the tool, in the form of advice to the user, can be tailored in response to the user's needs as indicated by their answers to the questions. Nevertheless, because the assessment design is dependent on the large range of issues and factors discussed in this entry, it is recommended that such tools are used in professional development sessions where there are opportunities for discussion, negotiation, and collaboration.

Cross-References

- [Information Technology and Assessment](#)
- [WhatsApp for Electronic Feedback and Assessment](#)

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Designs for Learning

- [Problem-Based Learning Online](#)

Developing Blended Learning

- [Blending Learning Provision for Higher Education, Integrating “New Ways” of Teaching and Learning](#)

Developing Professional Practice

- [Blending Learning Provision for Higher Education, Integrating “New Ways” of Teaching and Learning](#)

Development Environment

- [Teaching Software Design Techniques in University Courses](#)

Development Tendencies

- [Teaching with Computing, Educational Games](#)

DevOps

- [eXtreme Model-Driven Development \(XMDD\) Technologies as a Hands-On Approach to Software Development Without Coding](#)

Dexterity

- [Indications for Kinesthetic Learning Through Haptic Devices](#)

Dialogue-Based Tutoring Systems

- [Artificial Intelligence in Education](#)

Didactical Designs

- [Problem-Based Learning Online](#)

Didactics of Informatics

- [Computers in Secondary Schools](#)
- [Teaching About Computing](#)

Different Methodological Approaches to Considering the Adoption of ICT

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Synonyms

[Information communication technologies](#); [Innovation translation](#); [Technological innovation](#); [Technology acceptance model](#); [University education](#)

Background of the Original Research

This entry was based on initial research undertaken in 2006 in Thailand by Kripanont (2007). It involved interviews and surveys of academics in Thai Public Universities with the aim of better understanding determinants of these academics’ acceptance and usage behavior regarding information and communication technologies (ICT). The original research was analyzed using a modified version of the technology acceptance model (TAM), along with the use of structured equation modeling (SEM), but this entry re-analyzes it in a quite different way through the use of a framework based on innovation translation and actor-network theory (ANT) (Tatnall 2013).

ICT, the Internet and Thai Universities

Thailand has a population of 69 million and Internet penetration of 43%, up from 17% in 2006 when the original research was undertaken (Internet Live Stats 2016). The Thai public university sector is supported by the government and for some years the Thai Government had a policy of supporting IT to facilitate teaching and learning processes (Government of Thailand 2001), and so in 2006, there were networks that linked all state universities around the country, offering the possibility of the Internet to facilitate teaching and learning. In 2006, Thai National Plans (National Electronics and Computer Technology Center 2001; Office of the Education Council 2004) had consistent targets aimed at the use of ICT to support continuous learning. It was seen as essential for all academics in higher education to use ICT, and especially the Internet, as most students already did so (Office of the Education Council 2004).

Technological Innovation and TAM

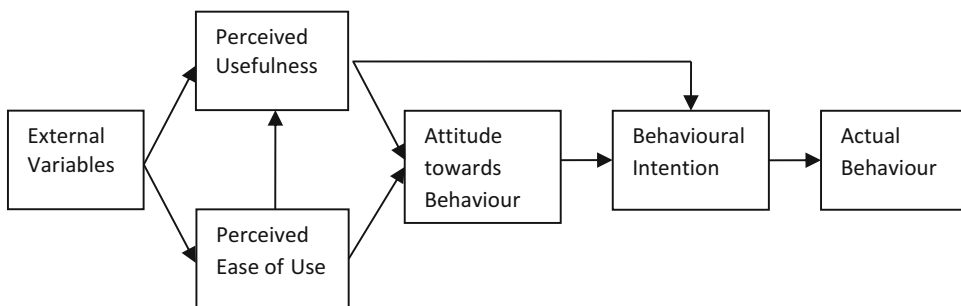
Exploring this research (Kripanont 2007; Kripanont and Tatnall 2009, 2011) involved the development of a modified version of the technology acceptance model (TAM) to describe the adoption of Internet technologies by academics in business schools in Thai public universities. TAM was developed from the theory of reasoned

action by Davis (1986, 1989) and assumes that a computer user acts rationally and systematically with all available information to decide whether or not to adopt this particular technology. TAM identifies determinants of acceptance and specifies causal links between the technology's *perceived usefulness* and *perceived ease of use* along with the individual's *attitude toward using technology* and *behavioral intention* in order to explain technology adoption (Davis 1986, 1989; Davis et al. 1989) (Fig. 1).

Innovation Translation (Informed by Actor-Network Theory)

Rather than focusing on just the technical aspects of an innovation and treating “the social” side of things as the context in which its development and adoption take place, actor-network theory (ANT) considers the world to be full of hybrid entities containing both human and nonhuman elements, and gives equal regard to each (Tatnall 2007). In ANT, the extent of a network is determined by actors that are able to make their presence *individually felt* (Law 1987) by other actors.

Innovation translation (Latour 1986, 1996; Law and Callon 1988) notes that innovations are often not adopted in their entirety but only after “translation” into a form that is more appropriate for use by the potential adopter. It uses these notions in an explanation of the adoption, or non-adoption of technology (Tatnall 2011).



Different Methodological Approaches to Considering the Adoption of ICT, Fig. 1 The technology acceptance model (Davis 1986, 1989)

Methodology for the Original Research

The original research employed survey methodology using semistructured interviews to gather preliminary data during an exploratory stage. Interview results were used to design a questionnaire for the next stage to collect the primary data. This was pretested, and a pilot survey conducted, but from the results of reliability, content validity, convergent validity tests, and data analysis of the pilot survey, a minor change was made to the questionnaire design before distribution (Kripanont 2007).

The questionnaires were distributed to 1,045 full-time academics, who have had some Internet experience, within 22 business schools in 24 universities in the Thai public university sector. Of these, 109 academics were on educational leave and 9 academics had no Internet experience, so the target population was 927. Because this was relatively small for a quantitative study, it was important to use all subjects in the population as targets of this survey (Sekaran 2003). After 3 months, the survey yielded a total of 455 usable questionnaires (response rate of 49%).

Research Model in the Original TAM Study

The main objective of the original research was to generate a modified model of technology acceptance, based on TAM, to best describe usage-adoption behavior by Thai academics. The generated model was expected to be both substantively meaningful and statistically well-fitting (Jöreskog 2006) and structural equation modeling was used in conjunction with the computer package AMOS. This research comprised two main stages (Kripanont 2007; Kripanont and Tatnall 2009, 2011):

1. Formulation of a technology acceptance model based on TAM and other models.
2. Generation of a technology acceptance research model that best described usage behavior of academics using the Internet in

their work. This was to make use of SEM through AMOS.

Previous Longitudinal Studies

For longitudinal studies of a new technology, behavioral intention to use was captured before actual usage behavior was measured. Venkatesh et al. (2003), for example, investigated behavioral intention and then usage behavior from the time of the initial introduction of the technology to stages of greater experience. Thus in a longitudinal study using TAM, the role of intention as a predictor of usage behavior is critical and has been well established in ICT (Ajzen 1991; Sheppard et al. 1988; Taylor and Todd 1995a).

The research model proposed for the original study was formulated on the assumption that individual reactions to use of ICT may influence actual usage and actual usage may influence intentions to use the technology (Venkatesh et al. 2003). The research model was based mainly on TAM (Davis 1989), TAM2 (Venkatesh and Davis 2000), C-TAM-TPB (Taylor and Todd 1995a, b), and UTAUT (Venkatesh et al. 2003) and specified the causal linkages between the five key concepts of: *perceived usefulness*, *perceived ease of use*, *social influence*, *facilitating conditions*, and *self-efficacy* as well as *actual Internet usage and intention* to use the Internet. The research model was formulated by theorizing these five constructs to play important roles as direct determinants of usage behavior and user acceptance.

Perceived Usefulness

In the original study, this was used as the core construct of interest and a direct determinant of usage behavior. According to TAM, it is expected that a person will use a particular technology if they believe that it would enhance their job performance (Davis 1989; Davis et al. 1989). Significantly, many models also theorized that perceived usefulness is a direct determinant of behavioral intention and usage behavior. Incidentally, *perceived usefulness* is analogous to *relative advantage* in diffusion of innovations (Rogers 2003).

Perceived Ease of Use

This is also theorized as a determinant of behavioral intention in TAM. In addition, many believe that there is strong evidence to support perceived ease of use as a direct determinant of usage behavior (Davis 1989; Gefen and Straub 1997; Igbaria et al. 1997; Szajna 1994; Thompson et al. 1991). This is analogous to *complexity* of an innovation by Rogers (2003), although in the opposite direction. Perceived ease of use is similar to effort expectancy (Venkatesh et al. 2003). Effort expectancy is defined by Venkatesh et al. (2003:450) as: “*The degree of ease associated with the use of the system.*” For the original study, perceived ease of use was considered to be a direct determinant of usage behavior because it was expected that an academic would use the Internet if they believed that the technology was easy to use.

Social Influence

In the original study, social influence was also used to determine usage behavior because it was expected that people may use the Internet if they thought that other important people *believed* they should use the technology. Social influence is defined here as “*The degree to which an individual perceives that other important persons believe he or she should use the technology/system*” (Venkatesh et al. 2003).

Facilitating Conditions

These are defined as “*The degree to which an individual believes that an organisational and technical infrastructure exists to support use of the system*” (Venkatesh et al. 2003). The empirical results indicated that facilitating conditions did have a direct influence on usage beyond that explained by behavioral intention alone.

Self-efficacy

Self-efficacy was defined in the original study as the internal notion of the individual and is related to perceived ability (Bandura 1986). With respect to ICT usage, it was anticipated that higher levels of self-efficacy would lead to higher levels of behavioral intention and ICT usage (Compeau and Higgins 1991). For this study, it was expected that self-efficacy would be a significant direct

determinant of usage behavior because the perceived ability of a person will influence them. The level of usage was expected to be related to the level of perceived ability.

User Behavior

Since an individual's stated preference to perform the activity (behavioral intention) will be closely related to the way they do behave, this assumption only applies when the behavior is under a person's volitional control (Ajzen and Fishbein 1980). Normally in Thai public universities, Internet usage by academics is by their own choice: they have volitional control, and the original research was conducted in this context.

Behavioral Intention

According to TAM, *behavioral intention* plays an important role in predicting behavior, but it is important to note that it is more predictive of behavior when individuals have had prior experience (Taylor and Todd 1995a, b). Since in this cross-sectional study individual academics already had experienced using the Internet at the time of the survey (2006), academics' behavioral intention was influenced by actual usage at this time.

Model Generation in the Original Study Using Structural Equation Modeling (SEM)

An objective of the original research was to generate a model of technology acceptance that best described usage behavior of academics with some Internet experience. This model needed to be one that was both substantively meaningful and statistically well fitting (Byrne 2001, 2006), and to achieve this objective, structural equation modeling (SEM) was used. SEM is a multivariate technique combining aspects of multiple regression and factor analysis to estimate a series of interrelated dependence relationships simultaneously (Hair et al. 2006; Schumacker and Lomax 1996). A structural equation model, or path model, depicts the structural relationships among constructs (Sharma 1996) and so SEM produces a

model of relationships among variables (Hayduk 1987). There are three important general strategic frameworks for testing structural equation models (Jöreskog 2006): strictly confirmatory, alternative model, and model generating.

1. For a strictly confirmatory approach, the researcher postulates a single model based on theory, collects the appropriate data, tests the fit of this model to the sample data, and then either rejects or accepts the model. No further changes to the model are made.
2. An alternative model approach has been sometimes used. After proposing several alternative or competing models all of which are grounded in theory following analysis of a single set of empirical data, the researcher selects one as most appropriate in representing the sample data.
3. This research was based on a model-generating strategy where the researcher could postulate and reject a theoretically derived model on the basis of its poor fit to the sample data, and then proceed in an exploratory way to modify and re-estimate the model. The idea is to locate the misfit in the model and so determine one that better describes the sample data.

By using SEM with AMOS (the software package of choice), the hypothesized model can be tested statistically in a simultaneous analysis of the entire system of variables to determine the extent to which it is consistent with the data. If fit is adequate, the model suggests plausibility of the postulated relations among variables. If it is inadequate, such relations are rejected. Despite the model being tested in each round, the whole approach is model generation rather than model testing (Byrne 2001, 2006).

Result: The Internet Acceptance Model

The Internet acceptance model developed in the original research posits three significant determinants of usage in teaching (TEACH): *perceived usefulness* (PU), *perceived ease of use* (PEOU), and *self-efficacy* (SE), and two significant

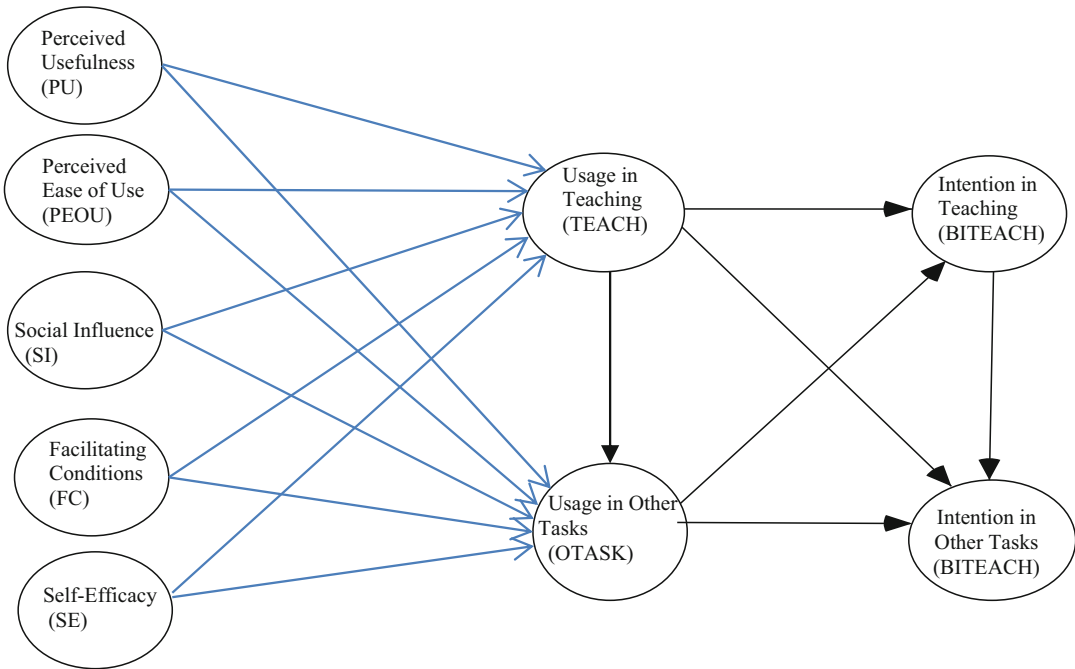
determinants of usage in other tasks: *perceived usefulness* (PU) and *self-efficacy* (SE). Social influence and facilitating conditions did not play an important role in influencing usage behavior. All direct paths (Fig. 2) between usage behavior and behavioral intention are statistically significant.

It can thus be suggested that academics used the Internet in teaching and in other tasks because of *perceived usefulness* (PU) and *self-efficacy* (SE) and noticeably in teaching. One more motivation to use the Internet was *perceived ease of use* (PEOU). This indicates that sometimes academics may not have used the Internet in teaching related tasks because they thought that there were obstacles related to using it. Self-efficacy was another important determinant, and whenever academics used the Internet, their self-confidence and perception that they were able to use the technology was significant.

An ANT Analysis of this Study

Analysis of this study was initially performed using the technology acceptance model to investigate the uptake of ICT in public universities in - Thailand. The study's sociotechnical nature, however, suggested that a reinterpretation using innovation translation informed by actor-network theory might be useful. While it is not possible to completely reinterpret an existing mixed methods study using actor-network theory as the questions that would be asked in interviews and the information obtained from the surveys would not be quite the same, there is still some value in reinvestigating the actors and interactions that may have been present (Al-Hajri and Tatnall 2011).

Whereas TAM is based on the assumption that a potential adopter is quite rational and uses information in a systematic manner to decide whether to use, or not to use this technology, innovation translation sees this quite differently. Innovation translation argues that just because a technology has been built and made available does not mean that it can automatically be assumed that organizations or individuals will want to adopt or to use



Different Methodological Approaches to Considering the Adoption of ICT, Fig. 2 Internet acceptance model – in experience and voluntary settings – five determinants (Kripanont 2007)

it, and even if an organization does adopt a new innovation, it may not use it in the way that its originator intended (Kripanont and Tatnall 2009, 2011; Al-Hajri and Tatnall 2011).

Innovation translation has the advantage of being able to easily explain examples of partial adoption, and of situations where what is actually adopted differs somewhat from what was proposed. In comparing the diffusion and translation models, Latour (1986) contends that in a diffusion model, an innovation is “*endowed with its own form of inertia and propelled from a central source.*” This enables it to move through space and time without the need for further explanation and makes it unstoppable except by the most reactionary interest groups. Once the innovation has been pointed out to people, then it should just be a matter of time before everyone, except the most immovable, recognize its advantages (McMaster et al. 1997). With the translation model, on the other hand, the initial idea hardly counts and the innovation is not endowed with autonomous power or propelled by a brilliant inventor (Latour 1996). Each potential adopter

“translates” the innovation into a form which they consider might be suitable for them. Callon (1986) suggests that the process of translation can be considered to have four aspects or “moments.”

- Problematisation – “how to become indispensable,” where one or more key actors attempt to define the nature of the problem so that they are seen as having the answer, and being indispensable to the solution of the problem (McMaster et al. 1997).
- Interestement – “how allies are locked in place.” This involves a series of processes attempting to convince and impose roles, defined in the problematisation, on other actors.
- Enrolment – “how to define and coordinate the roles.” Enrolment will follow through a process of coercion, seduction, or consent (Grint and Woolgar 1997), leading to the establishment of a solid, stable network of alliances. The innovation has now been adopted.
- Mobilization – “are the spokespersons representative?” This final step occurs as the

proposed solution gains wider acceptance (McMaster et al. 1997) and an even larger network of absent entities is created (Grint and Woolgar 1997) through some actors acting as spokespersons for others to promote adoption of the innovation (Tatnall 2009).

Whereas TAM tries to identify the perceived usefulness, ease of use, and intention to adopt by the potential adopter, ANT instead works to identify actors and their associations and interactions with other actors. Although the interview questions used in an ANT study would have been different, it is still possible to indicate how the results could be interpreted. In an ANT analysis, we begin by identifying the actors. Law (1987) describes an actor as any human or nonhuman entity that is able to make its presence *individually felt* by other actors. The actors in this case can be seen to include: the Government of Thailand, the Ministry of Education, Thai public universities, university Presidents, university academics, university administrative support staff, university technical staff, students, overseas academics, Thai Government policy, Thai e-university plans, research university plans, Thai culture, Thai language, Thai habits of reading and writing, Ministry of Commerce policy, university Councils, the Internet, university computers, and university ICT infrastructure.

The original study, and this entry’s re-analysis, was a study of innovation in investigating whether a particular technology was accepted and how this

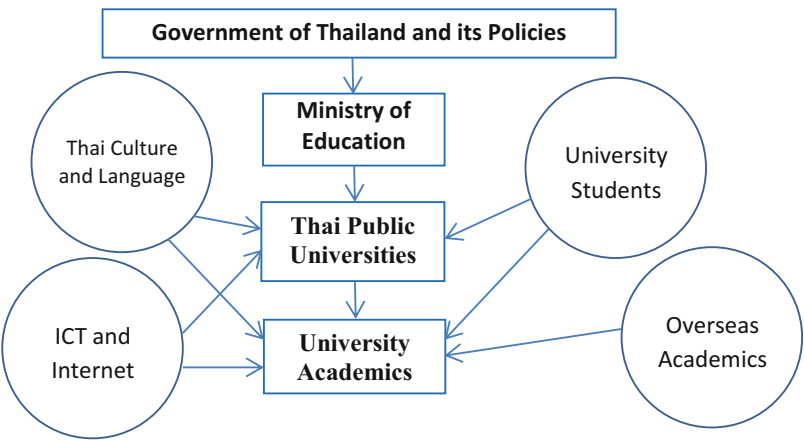
occurred. When framed by innovation translation, the approach involves looking at how each of the actors relates to the four moments of translation. But what it is rather more difficult to now is to fully investigate interactions and associations between these actors. Some likely interactions between the main actors in this study are shown in Fig. 3.

We will now consider each of the major actors and their interactions and associations in terms of these moments of translation and speculate on how this may have occurred. As it is not now possible to go back and directly question the actors, some of this must be quite speculative.

ICT and Education Policies of the Government of Thailand

For some years, the Thai Government has had a policy of supporting ICT to facilitate teaching and learning processes (Government of Thailand 2001) and so in 2006 all Thai public universities had computer facilities and networking to facilitate teaching and learning. In 2006, Thai National Plans (Office of the Education Council 2004; National Electronics and Computer Technology Center 2001) had consistent targets aimed at the use of ICT to support learning. It was seen as essential for all academics in higher education to use ICT and especially the Internet, as most students already did so (Office of the Education Council 2004).

Different Methodological Approaches to Considering the Adoption of ICT, Fig. 3 Major interactions in university academics’ adoption of ICT



In 2006, the Thai Government's National IT Policy (IT 2010) targeted Thailand moving from being a "dynamic adopter" to "potential leader" on the basis of the United Nations' standard (National Electronics and Computer Technology Center 2001), and the government had a policy of supporting ICT to facilitate teaching and learning processes. The Thai Government's National Education Plan (2002–2016) (Office of the Education Council 2004) aimed "to develop human learning into a learning society" and to "increase knowledge leading to a knowledge-based society by development of technologies for education to support continuous human learning." The policy stipulated that by 2010 all schools would be able to connect with the IT network, and that IT would be used as part of the teaching-learning process at all levels. In accordance, the Ninth National Economic and Social Development Plan (2002–2006) stated that: "*Information Technology should be adopted to facilitate teaching and learning processes and teaching instruments to disseminate information and knowledge*" (Government of Thailand 2001).

Ministry of Education Policy and Thai Public Universities

One of the strategies of the Ninth National Economic and Social Development Plan (2002–2006) (Government of Thailand 2001) and the National Education Plan (2002–2016) (Office of the Education Council 2004) was to provide new knowledge via research. Previously, the organizational culture of the university sector was mainly teaching-oriented. But in accordance with the National Plans, each Thai university had to develop strategies to become research-oriented as this would contribute significantly more benefits to the country than being a teaching-oriented university.

The Government's *problematization* of Internet adoption by universities under the direction of the Ministry of Education probably related to what it saw as the benefits to increased national efficiency and knowledge, as well as economic benefits. Its *interessement* probably just involved a directive to the Education Ministry which meant

that they then had no choice but to be enrolled. Whether all these actors were then fully mobilized, however, is quite another matter.

Research University and E-University Plans

It was required of public and state-supervised universities to follow the National Plan and National IT policy and so they had to set a goal to become an e-university. For public universities in Thailand, the President operates the university according to the policy laid down by the University Council. University academics who acknowledge and support the research university plan will act differently to those who do not support it. It was considered that those who supported the plan would, most likely, prepare themselves for the future by trying to use the Internet to search for information for their research. On the other hand, academics who do not support this plan may concentrate only on teaching and not pay any attention to research.

The *problematization* of research university and e-university plans by universities followed directly from that of the Thai Government and probably related to what it saw as the benefits to teaching and research by adopting ICT. The universities probably did not all engage in the same form of *interessement* to support this *problematization*, but many would have done everything possible to encourage their academics to give it support and become *enrolled*. To convince its academics of the value of making use of ICT, a university could have done things like offering training and professional development activities or possibly some form of dis-incentive for not getting involved. Some academics would have become fully *enrolled* and gone on to become *mobilized* to try to encourage their colleagues, while others probably would not. Further interviews could have shed more light on this matter.

Thai Language and Culture

The Internet has had a profound impact on knowledge and worldviews through use of search engines such as Google giving millions of people worldwide instant access to a vast amount and diversity of information. The Internet represents

a sudden and extreme decentralization of information and data compared to encyclopedias and traditional libraries, but the Internet's predominant language is English. Language, according to Hofstede (1980), is one of the layers of culture and this presents a problem for those speaking the Thai language (Miniwatts Marketing Group 2006). Few databases have been developed in Thai to support higher education, meaning that typically people have to search the Internet in English to get the information they need.

Thai academics normally follow a western style in establishing the university teaching curriculum and make use of English language text books in preparing teaching materials. Although several interviewees stated that they thought that Thai language was an obstacle in using the Internet, most thought that it was not. According to the Office of Education Council of Thailand (2004), the national culture of the Thai people tends to involve the habit of not much reading and writing, and this can have an effect on Internet use (Kripanont 2007). From the preliminary interviews, one interviewee, who is expert in ICT in many Thai Government projects, suggested that this could be a problem that needs further investigation.

University Academics

How Thai university academics themselves *problematize* adoption and use of ICT is an important question, but one that would only be properly answered by more interviews. It is likely that some would *problematize* it as something very useful to their teaching and research while for others it would be just another inconvenience to make their lives more difficult. How they would respond to their university's attempts at *interessement* would also be interesting to observe. Something else about the university academics that could be investigated further is in relation to an aspect of Thai culture where differences of opinion are not usually openly expressed during meetings (Charnkit 2011). Respect for those in higher positions, such as a university President, means that following their policy is an important principle that it is natural to follow.

University students would most likely provide strong *interessement* toward academics' adoption of the Internet as they typically would have good knowledge of ICT and would be keen to see it used by their lecturers. Another interesting investigation could see how overseas academics, met at conferences, would affect Thai adoption of the Internet to communicate.

ICT Infrastructure

This nonhuman actor, if it had a voice, would probably have seen a big advantage in the value of universities making more use of ICT as it would potentially make knowledge more accessible and provide another important use for itself. Its *problematization* therefore would have been in favor of this increased use and it (or rather its proponents) would have done everything possible to convince others of this.

Conclusion

The original TAM study concluded that ICT and Internet behavioral intention were significantly influenced by actual usage, as the more experience an academic had of the technology the more significantly this affected their intention to use it in future. Perceived usefulness and perceived ease of use were each shown to have significant influence on usage behavior, particularly in teaching. Self-efficacy was also found to be another important determinant in this research as it has a strong influence on usage behavior. The study also found that social influence had no significant influence on usage, possibly because some academics already had some 6–10 years of Internet experience.

To an ANT researcher, the TAM criteria to determine adoption: perceived usefulness and perceived ease of use seem rather self-evident, not offering much in the way of explanatory power. Whereas TAM takes a fairly mechanistic approach to whether various factors are likely to have increased a potential adopter's perceived usefulness of the innovation and whether they have increased their perception that it is easy to

use, ANT makes no such prior assumptions. ANT looks instead at the interactions and associations between all the actors, making no assumptions on what these might be. ANT also looks seriously at the contributions of actors including Government policy, Thai culture and language, influences from academics in other countries, influences of the students, and the technology itself. Instead of looking only at a potential user's perceptions of the technology, innovation translation allows the possibility that this user might not want to use it in the way originally suggested: that they might want to "translate" it into another form before adoption.

This re-interpretation of a TAM study of the adoption of the Internet by academics in business schools in public universities in Thailand made use of actor-network theory and innovation translation in place of the original framework using the technology acceptance model. Of course, if an ANT approach is to be used in any research project, then ideally it would be used from the beginning of the study so that the data collection and interviews reflected the sort of questions required to approach the problem from an ANT perspective. Here, it would have been good to find out what university academics thought about the value of the Government's e-university and research university plan. It would have been good to find out more about Thai culture and language and how this might have influenced Internet adoption and use, and there are other questions that it would have been good to ask. Nevertheless, it is possible to do some "after the fact" re-conceptualization and re-analysis of the data from a TAM study to make use of an innovation translation lens.

Cross-References

► Modeling the Process of Information Technology Innovation in Education

Acknowledgments This entry owes a great deal to the work of Dr. Napaporn Kripanont who conducted the original study in 2006 as part of her Ph.D. research at Victoria University. Sadly Napaporn died in 2012. She was an

academic in the Faculty of Business Administration at Kasetsart University, Bangkok, Thailand.

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Digital Assessment for Learning

► Clicker Interventions, Promoting Student Activity and Feedback at University Lectures

Digital Citizenship, A Sociocultural Snapshot

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Synonyms

Concepts; Culture; Democracy; Principles; Society; Values

Changes in society impact education systems. The term “*wicked problems*” (Rittel and Webber 1973) has been used to describe complex problems that may span economic, cultural, political, and educational domains in association with societal change. With the increase in the use of digital technologies to support learning and teaching in twenty-first century educational contexts, it has been suggested that educators and students need an increased capacity for “*wicked problem-solving*.” The sociocultural contexts students experience outside of the school environment influence the choices they make when engaging with digital technologies and the way they communicate when they do so. Sociocultural theory proposes that a range of social, cultural, institutional, and historical factors influence an individual’s behavior, thinking, and knowledge construction, and that these factors in turn influence their psychological, emotional, mental, and spiritual well-being. These multiple spheres of influence may be perceived as complementary or conflicting when considered from the young person’s perspective. The communication styles and discourse evident within their home, community, and informal social group settings will likely differ from those endorsed within the more formal settings they experience, including school. For example, the use of emoji’s (a small image used to express an emotion/idea), acronyms (e.g., LOL = laughing out loud) in a text message or email would likely be deemed unacceptable within a piece of formal writing designed to address the requirements of the school curriculum.

There are proven benefits for young people who use digital technologies. For example, digital technologies can enhance the ability for young people to communicate, collaborate, and co-create by bridging the traditional boundaries of space, time, and formal/informal settings. Digital technologies can enable the convergence of traditionally separate modes of learning. Digital technologies can foster the development of “soft” skills (e.g., experimentation, remixing, creativity), and participation within online communities can play a positive role supporting identity development. However, a range of risks have also been associated with the use of digital technologies by young people. Risks can be defined as actions that included an element of uncertainty and that can potentially have undesirable outcomes. Perceptions of risk differ, as perceptions are impacted by an individual’s values, beliefs, prior experiences/age, personal preferences, social setting, and judgment. Therefore, activities that may be perceived as being “risky” to adults may be perceived as “opportunities” by young people.

To minimize risk, there has been a global call for educational institutions to ensure students develop the dispositions, capacities, and competencies that will foster safe and effective participation within complex digital environments, within both formal and informal settings (UNESCO 2015). While schools have a legal responsibility to establish and maintain safe learning environments for students, and ensure students use digital technologies safely and responsibly within the school environment, schools also have an ethical responsibility to ensure they prepare students to do so outside of the school environment. Digital citizenship programs have been promoted as an effective way to address digital safety and responsible use in educational contexts. Unfortunately, lack of consensus defining “*digital citizenship*,” digital citizenship frameworks or how digital citizenship is best addressed within school programs has added complexity to this educational endeavor.

Multiple, contested definitions exist for the term “*citizenship*.” Simsek and Simsek (2013) suggest citizenship was historically associated with power of individuals within the process of

social decision-making, impacted by socioeconomic status, gender, age, and historical and cultural values. Mutch (2013, 52) suggests five categories to conceptualize citizenship: citizenship as *status* (i.e., legal rights and responsibilities within a political entity), citizenship as *identity* (i.e., religious, political, ethnic, and national), citizenship as the *democratic ideal* (i.e., democracy, freedom, and human rights), citizenship as *public practice* (i.e., laws, statutes, customs, traditions, and cultural norms), and citizenship as *participation* (i.e., actions that embody community-mindedness, national activism, global awareness). Tolson (2008) proposes that technology has redefined the meaning of citizenship in the digital age, defining citizenship as “a cultural idea, infused with moral meaning, encompassed by normative values and expectations that all derive from the social, historical and cultural context of the times” (Ibid., 5). Normative values can be described as the underpinning beliefs that govern what people deem to be important, informed through the social and cultural contexts they interact with, and experience, throughout all aspects of their lives.

There is also no universally recognized definition for the term “digital citizenship.” Each definition will reflect both the orientation and perception of the writer. Definitions may contain indicators that describe a variety of different things; including behaviors, skills, knowledge, capacities, conditions, challenges, choices, and/or outcomes. For example, Ribble (2010) describes digital citizenship as “the norms of appropriate, responsible behaviour with regard to technology use” (Ibid., 10), while Isikli (2015), who describes digital citizenship as a socio-technical phenomenon, proposes it is the “cultural, technological, economic and social conditions that accompany the digitalisation of citizenship” (Ibid., 25). The notion of balancing individual rights with collective responsibilities is a challenging facet of digital citizenship when considered from a sociocultural perspective. Given the centrality of values within the concept, questions arise such as; whose individual and collective values were, would be, or should be “represented” when defining these values, should

the values of individuals be deemed more important than those of the collective, and in what ways do these values differ within different cultural contexts? Rowe (1992) suggests that “moral values and beliefs are relative, and pluralistic communities are based on the fundamental principle that individuals have the right to their own values and beliefs insofar as these do not diminish the rights of others” (Ibid., 179).

When digital citizenship is considered from a sociocultural perspective, it is evident that the social groups a person participates in and belongs to, and the beliefs and traditions prevalent within these groups as situated within their cultural context, will influence how they choose to act when using digital technologies. This suggests that frameworks to support the development of digital citizenship will be most effective when they are designed for specific sociocultural contexts. The following model for digital citizenship, developed in Aotearoa/New Zealand, provides one example of a culturally located digital citizenship framework.

Digital technologies are becoming increasingly commonplace in schools and homes in Aotearoa/New Zealand and are being used by young people at an increasingly earlier age. Corresponding with this is growing concern regarding the safety, behavior, and wellness of young people who use digital devices to engage with digital content and participate within digital communities on a regular basis. In 2015, the UNESCO (United Nations Educational, Scientific and Cultural Organisation) Asia and Pacific Regional Bureau for Education reviewed the status of digital citizenship in the Asia-Pacific regions, of which Aotearoa/New Zealand is a member country (UNESCO 2015). The recommendations presented within the project summary included the need to empower young people by ensuring they learned about their rights and responsibilities through values education and the imperative to address gender equality, diversity, and cultural appropriateness in the digital age. UNESCO further advocated that digital citizenship frameworks and associated resources needed to be contextualized to provide country-specific messages and material (Ibid., 44). The report also

called for the international research community to develop a “*research agenda*” to inform interventions that were responsive and customized to regional contexts and needs.

However, digital citizenship is not currently specified within the national “*New Zealand Curriculum*” document (Ministry of Education 2007). In addition, while the USA, for example, have the ISTE standards to guide educators redesign learning and teaching for the digital age, no such standards exist to support schools across the New Zealand education system. In response to the growing imperative to address digital citizenship in a cohesive, culturally located manner, Netsafe (2016), the key independent nonprofit organization that provides support in relation to online safety in school, community, and industry contexts in Aotearoa/New Zealand, published a white paper in 2016 entitled “*From Literacy to Fluency to Citizenship: Digital Citizenship in Education.*” Within this document, Netsafe proposes that the proliferation of abstract concepts and contested definitions of digital citizenship have hindered schools’ ability to enact programs in this area. They advocate for “a consensus view” of the values, aims, and knowledge underpinning digital citizenship in Aotearoa/New Zealand to be developed, so schools can move forwards (Netsafe 2016, 3). To support this, they presented an updated digital citizenship definition and framework that acknowledges the bicultural context of Aotearoa/New Zealand. The framework specifies six guiding principles that should underpin all approaches to digital citizenship in Aotearoa/New Zealand. Importantly, each principle is also expressed in the form of a Māori value. Māori values are derived from traditional Māori beliefs, and act as lenses in the ways Māori people, the indigenous people in Aotearoa/New Zealand, interpret and experience the world. The Māori values and principles are woven together as illustrated below:

- *Ako* (all people are both teachers and learners): Young people are active agents in the design and implementation of digital citizenship, including approaches to online safety.
- *Whānau* (culturally appropriate relationships that provide a sense of belonging):

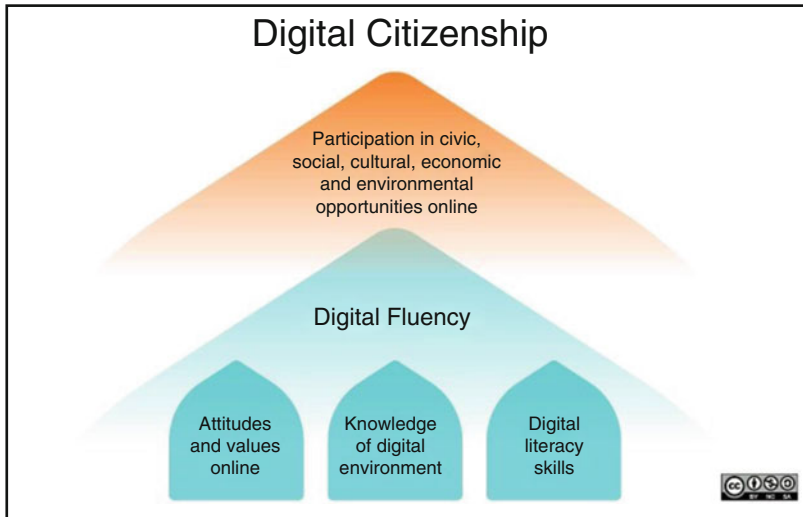
An unbounded, coherent home-school-community approach is central to the development of digital citizenship and online safety management.

- *Manaakitanga* (respect, care for others, generosity): Approaches to digital citizenship are inclusive, responsive, and equitable in design and implementation.
- *Wairuatanga* (well-being, spirituality, and intergenerational transmission): Digital citizenship in action positively contributes to well-being and resilience development enabling safer access to effective learning and social opportunities.
- *Mahi tahi* (collaboration, working together): Digital citizenship development and online safety incident management are fostered through partnership approaches, coherent systems, and collaboration (p. 4).
- *Kotahitanga* (unity, collective action): Evaluation and inquiry underpin the ongoing design of digital citizenship approached, based upon rich evidence from young people and their whanau (i.e., family) (Ibid., 4).

The Netsafe definition of digital citizenship (Fig. 1) emphasizes development in three key areas:

- *Digital literacy skills*: Skills and strategies to access technology to communicate, connect, collaborate, and create.
- *Attitudes and values online*: Attitudes, underpinned by values that support personal integrity and positive connection with others.
- *Knowledge of digital environments*: Understanding of the digital environments and contexts in which they are working and how they integrate on/offline spaces (Ibid., 3).

Netsafe propose that developing the above will enable young people to develop the “*digital fluency*” required to effectively participate in the social, economic, cultural, civic, and environmental opportunities that are increasingly available in online environments. In describing what their “ideal future” would be in response to this framework, Netsafe proposes there will be movement



Digital Citizenship, A Sociocultural Snapshot, Fig. 1 The Netsafe definition of digital citizenship. (Reprinted with permission) (Netsafe 2016)

towards *communities taking action*. If consensus can be reached, and the framework implemented across educational contexts in Aotearoa/New Zealand, the desired outcome for students situated within this sociocultural context will potentially be the realization of vision statement described in the *New Zealand Curriculum* (2007): the development of confident, connected, actively involved, lifelong learners.

In summary, schools have a legal and ethical responsibility to help students develop the digital fluency that will enable them to participate safely and effectively within the digital realm. However, given the sociocultural contexts students experience outside of the school environment will continue to influence the choices each individual makes when engaging with digital technologies, the responsibility to do so also belongs to friends, parents, family, and members of the wider community.

Cross-References

- Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption
- International Reports (Including OECD)

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Digital Fabrication

- [Makerspaces](#)
-

Digital Formative Assessment

- [Clicker Interventions, Promoting Student Activity and Feedback at University Lectures](#)
-

Digital Game-Based Learning

- [Computers in Primary Schools, Educational Games](#)
-

Digital Games-Based Learning

- [Shared Regulatory Planning in Minecraft](#)
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Digital Learning

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Digital Learning in Mathematics

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Digital Literacy

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 - [Educative Value of Digital Storytelling](#)
-

Digital Literacy, Creativity, and Autonomous Learning

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Synonyms

[Autonomous learning](#); [Creativity](#); [Digital literacy](#); [DIY](#); [DIYLab activity](#); [Visualization of learning process](#)

Introduction

Today, most people use technology not only during their formal education, in their professions or jobs but also in pastime activities in which they are motivated to produce a digital artifact (e.g., music, art, movies, apps for mobiles) or to solve problems related to their interests or hobbies. These pastime activities have a very strong creative potential. At the beginning, people usually have an idea or a problem to consider without having any notions about which technology would be needed or even if they are capable of using such technology (see [DIY](#) or [makerspace initiatives](#)).

People having such problems use technology to find solutions. In such cases, they rarely have any prior specific training and they start learning autonomously in their own time, using their own way and having in mind their own idea of digital artifacts. As a result of their creative approach, they may come up with one or more “original” solutions.

The development of young people’s skills to use digital technology is not only a school issue provided by the curriculum but also mainly derives from their day-to-day experience, interest, and needs outside the school context. Young people tend to learn from one another in their free time how to use technology, share with each other what they have done with technologies, consult

each other, and discover how to use technology and for what. Consequently, this entry aims to present growing digital literacy through creativity and autonomous learning.

Main Concepts

The DIYLab, being based on do-it-yourself (DIY) philosophy, is an example of an innovative approach to improve digital literacy through creativity and autonomous learning.

Digital Literacy

There are many definitions of digital literacy. At present, teacher educators and researchers from most of EU countries accept the concept of digital literacy defined by the EC JRC (Vuorikari et al. 2016: 9) and its five competence areas (information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving). Digital literacy is rather a more complex concept. Thus, Eshet-Alkalai's (2004) conceptual model of digital literacy befits this entry. Eshet-Alkalai (2009: 93) posits that "digital literacy involves more than the mere ability to use software or operate a digital device; it includes a large variety of complex cognitive, motor, sociological, and emotional skills, which users need in order to function effectively in digital environments."

How can one develop his or her knowledge and skills to use digital technology? For many reasons, formal education is increasingly unable to provide and to offer pupils highly sophisticated and interesting activities with digital technology to contribute to their development of digital literacy. Robinson (2011) suggested that "conventional approaches tend to crush students' natural inclinations toward creative and divergent thinking." (Henriksen et al. 2016: 28). The digital literacy of young people is growing more and more out-of-school in specific activities, and this is often due to the immediate sharing of this experience among young people. "Technology changes rapidly, and it is not surprising that its integration into education still finds disappointing levels of

penetration and success" (Mishra 2012: 13–14). This is further evidenced by a number of studies among adults finding "that only about 10 per cent of learning represents formal learning in the workplace, compared with 70 per cent self- or on-the-job learning and 20 per cent peer-to-peer learning" (Grant-Clement 2017: 8).

Creativity

There are many interpretations of creativity. Warner (2000: 11) defines "creativity" as "a human act or process that occurs when the key elements of novelty, appropriateness, and a receptive audience in a given field come together at a given time to solve a given problem." Creativity involves an original approach to solving a problem combined with invention in finding a solution or producing something new. In the creative process, novelty reflects one's imagination, experiences, and thinking. The product may be aesthetically beautiful (e.g., artwork, music composition, or architecture construction) or ideationally original (e.g., Maxwell's equations). Sometimes, to be creative means to do something useful or beautiful in another way than before or than others do. Browning (2008: 213) posits "creativity involves invention, discovery, curiosity, imagination, experimentation and exploration. During the creative digital process there is a transformation from something known to something not previously known."

Digital technology offers many sophisticated tools to demonstrate and to develop our creativity. "We have seen an incredible flowering of creativity and innovation fuelled by the capabilities of such technologies. From Google to Facebook, from cloud computing to YouTube channels, digitality has altered how we live, work and connect with each other" (Henriksen et al. 2016: 27). Henriksen et al. (2016: 27) proclaim that creativity is "deeply connected to issues of technology integration, so these issues of creativity and technology can be considered in tandem." Hence, bringing creativity and literacy together can be a powerful tool in teaching and for learning, too. Nevertheless, we, the authors, wonder if technology is making us more creative.

A modern society needs educated and digitally literate people who have a creative approach to work. Unfortunately, in schools, digital literacy development is still focused on user skills. Fortunately, a key European Commission document has introduced into the concept of digital competency a requirement of creatively using digital technologies as a skill “to use digital tools and technologies to create knowledge and to innovate processes and products” and “to engage individually and collectively in cognitive processing to understand and resolve conceptual problems and problem situations in digital environments” (Vuorikari et al. 2016: 9).

Creativity with digital technology can have a different form. One of them is digital story-telling. “When students are engaged in the process of creating a digital story, they synthesise a variety of literacy skills for the authentic product: researching, writing, organizing, presenting, interviewing, problem-solving, assessing, as well as employing interpersonal and technology skills” (Baggett 2007: 180). Another example how “computing technology can be utilised to enhance our creativity within the learning process” and how digital literacy can be improved through creative projects is described by Smarkusky and Toman (2016: 35–36). They show how students of computer science or engineering “utilize technology as a means to convey their creativity, artistic design, and appreciation of the Arts. Since the creation of digital musical scores, animations and software applications share a similar development process, active-learning exercises using a variety of technologies, provide students with an opportunity to enhance learned concepts in both disciplines,” computer science and the Arts. “While experiencing the project development process, students are learning object-oriented terminology, animation frameworks, computer programming, distributed computing concepts, and principles of music theory” (Smarkusky and Toman 2016: 35). Interesting creative initiatives can also be found on the Scratch website (e.g., in programming a design of clock).

Some authors put digital literacy together with a traditional approach to literacy (as ability to read, write and communicate) only adding that

technology has been changed as how to express something in writing, from which resources we can read (locating and consuming digital content), which tools we can use for communication (Spires et al. 2012). Recently, creativity is frequently put together with the ability to create digital content. Byrne et al. (2018) show that a pedagogical model Bridge21 which consists of seven phases (setup, warm up, investigate, planning, create, present, and reflect) can be a promising approach to digital literacy development in everyone’s free time, based on his/her creativity and a strong motivation to do something completely new and interesting. “It incorporates many elements known to be conducive to teamwork; self-directedness, creativity, and positive self-driven experience.” (Byrne et al. 2018: 138).

Autonomous Learning

According to Beckert (2007), the term, “autonomy” is derived from the Greek words, “autos” (self) and “nomos” (rule or manage). “Autonomy in learning” is defined by Benson (2001: 47) as “the capacity to take control of one’s own learning.” Researchers in the field of education use different terms to explain autonomous learning. Some of these can be listed as “self-directed learning” (e.g., Ladell-Thomas 2012; McLoughlin and Lee 2010), “self-guided learning” (e.g., Welsh 2007), “self-taught learning” (e.g., Baker 2016), “self-efficacy in learning” (e.g., Livingstone and Helsper 2010), and “self-initiated learning” (e.g., Tour 2017). In this entry, the term “autonomous learning” is used.

As far as digital literacy is concerned, Ting (2015) posits that digital literacy involves autonomous learning, because autonomy in digital literacy develops when students try to resolve the difficulties they encounter when exploring the web and collecting resources for learning. Especially, online informal learning settings where learning takes places out of school, via social media, YouTube, Facebook, Twitter, wiki software, makerspace initiatives, or DIYLab, are the platforms where students are prone to become more autonomous in learning. As argued by Meyers et al. (2013: 356), “informal venues of learning and development are important spaces

where digital literacy is both employed and cultivated.” They (2013: 360) also emphasize the importance of learner autonomy in online informal settings since “informal contexts can support youth development of digital literacy by giving them problem-based challenges that support practising the application of ‘habits of mind’ to everyday situations and real-world scenarios.” McLoughlin and Lee (2010) argue how online informal learning environments enables students to direct their own learning since students select tools and collect resources to organize, create, and shape their learning content and tasks to learn more effectively and efficiently. Whereas, Lotherington and Jenson (2011) highlight that, in order to use online informal learning settings, students should be able to exchange, source, and learn from accurate material. Additionally, students should critically engage, analyze, and evaluate materials that they retrieve from the web.

Digital literacy necessitates that the user is able to self-manage his/her learning, to use and work with the technology, to exploit its functions, and to discover further functions and possibilities of technology in order to develop greater digital literacy.

DIY (Do-It-Yourself)

The concept of DIY is not totally new. It can be found when speaking of the development, for example, of amateur radio as a hobby. The DIY movement has developed and spread incrementally into different branches (technical education, art, science, etc.). It has common features: it brings together enthusiastic people (who have the same aim and interest) to solve in a creative way, interesting problems in their field and mutually to share “manuals” on how to proceed or how “you can do it yourself.”

Globally, there is a generation of DIY enthusiasts and supporters who join in various communities or networks. There is nothing that could limit activities of this generation of creative and thoughtful people; if they need to know something to be able to realize their DIY ideas, they learn from one another. DIY-ers very often use digital technology for their creative initiatives. The DIY generation visualizes stories to

document the process explaining how problems were solved to be shared as tutorials by others. Freedom to make and to create using digital technology is perceived as freedom of access, in the choice of tools and technology, and a release from reliance on specific software and hardware tools; it is using a variety of resources, making copies and sharing outcomes and methods.

Digital literacy can be improved through DIY activities cross different disciplines (technical education, Art, science, engineering, amateur radio, etc.). It has common features: it brings together enthusiastic people (who have the same aim and interest) to solve interesting problems in a creative way in their field and mutually to share “manuals” on how to proceed or how “you can do it yourself” (Černochová et al. 2018: 377). The idea of DIY can potentially contribute to further mastery in the use of digital technology and consequently improve digital literacy.

According to Kafai and Peppler (2011), it is possible also to incorporate DIY activities into programming, designing models, constructing robots, and creating manuals (tutorials) on how to do or how to learn something (for example, how to count using an abacus). Thus, DIY can potentially contribute to further mastery in the use of digital technology and consequently improve digital literacy.

The EU project DIYLab (Do it yourself in education: Expanding Digital Competence to Foster Student Agency and Collaborative Learning) implemented into school education DIYLab activities as a learning model based on DIY philosophy which is a student-centered, heuristic approach to learning and problem-solving and which implies six pedagogical principles for approaches to learning (Table 1). A key aim of DIYLab activities beyond solving a problem is to provide a manual on how to solve the problem. This “handbook” is then published in a form which can be shared with others – the best and easy to understand way is in a visible form (e.g., video, animation). The requirement to visualize a learning process about “how the problem can be solved” as a message for others follows several reasons. Firstly, visual tools are normally understood as comprehensible regardless of which

Digital Literacy, Creativity, and Autonomous Learning, Table 1 Six pedagogical principles for a design of DIYLab activities (Černochová et al. 2018)

Feature of DIYlab activity	Idea	Authors, resources
(1) To support collaborative learning	Members of DIY communities collaborate mutually	
(2) To have the characteristics of inquiry-based teaching and learning methods	DIY communities dedicate their time to original problems which have not been solved and which are different to traditional school tasks	
(3) To support transdisciplinary knowledge	To enable pupils to bring into school interesting ideas from the extracurricular environment and to create conditions for their exploration. If pupils have an interesting problem to be solved, they do not worry about which school subject it relates to	Sancho-Gil et al. (2015)
(4) To contribute to autonomous/self-regulated learning	Documenting how to proceed for others may be perceived as an author's self-reflection of his/her learning	Jocson (2012: 300)
	DIY communities enjoy finding a solution	Kamenetz et al. (2010: 20)
	"Building new tools and paths to help all of us learn"	
(5) To contribute to digital literacy improvement	"DIY youth voluntarily spend a lot of time in intense learning, they tackle highly technical practices, including film editing, robotics, and writing novels among a host of other activities across various DIY networks"	Kafai and Peppler (2011)
	To develop <i>photo-visual digital thinking skill</i> as a component of digital literacy	Eshet-Alkalai (2009: 3219) Eshet-Alkalai (2004: 93)
(6) To be connected with the curriculum	School curriculum	

languages we speak. Secondly, we are all increasingly surrounded by visual stories (e.g., YouTube, animated instructions for passengers how to behave during a flight).

An Example How Creativity and Autonomous Learning Can Contribute to Digital Literacy Development

MajaPaja is a student at a lower second school in the Czech Republic. She enjoys recording and editing digital videos and sounds in her free time and even though it was not an assignment from her school. Her father is an ICT teacher at secondary school. She produced a sound story with using only sound effects and posted her story on YouTube. MajaPaja also posted another YouTube video which she described how she produced her story with using only sound effects. Her approach

to learning with digital technology was described based on Moore's (2015) five stages of creative process (Table 2).

Inspiration: MajaPaja's father inspired her to create a sound story using digital technology without any words. She decided to compose the story in her free time as a voluntary initiative. It was for her a challenge to do something which she has never done before.

Percolation: The main problem for MajaPaja was what the story was about; she had no idea. Later, she prepared a scenario for her story-telling. In fact, the structure was particular sequences about a boy who would like to visit his girl-friend by a car (Table 3). MajaPaja did not use any particular existing story that most people know from films, books, and plays. Maybe she based her story on her experiences with specific sounds such as the voices of birds or sounds of animals.

Digital Literacy, Creativity, and Autonomous Learning, Table 2 Moore’s five stages of the creative process

Five stages of the creative process	Definition
Inspiration	Immersing oneself into their subject and aspirations
Percolation	Retaining ideas and potentially refining them before expressing them openly or presenting them in some explicit form
Preparation	Gathering information to produce the intended work
Creation	Producing the intended work
Reflection	Publishing the intended work on the Internet or displaying it somewhere to receive feedback from the others

Digital Literacy, Creativity, and Autonomous Learning, Table 3 Scenario for a MajaPaja’s sound story

	Scenario – sound story
At home	A boy is sleeping. He is snoring. He is gaping. WC. He is preparing breakfast. He is eating. He is washing in the bathroom. He is putting on his clothes. He runs his computer and he starts to read and answer e-mails. He is chatting with his girlfriend
Car	The boy goes out on the street. The boy starts the car. Driving the car. The boy listens to music in his car. An accident: the car is broken. He is bloody
Forest	The boy is calling by mobile. He is bloody. He comes out the car. He is walking. Some sounds in the woods. Sounds of wildlife and birds. A bear. The boy is fleeing. He is losing heart. He is breathing excitedly. A duel with a bear. The boy dies
End	Phone calls. Call. Cry

Preparation: MajaPaja first generated ideas about her sound story for a scenario (Table 3) and then she started producing her sound story. For her to find sounds, there were two possibilities. The first one was to download the sound recording application to her mobile phone or the second was to browse on the internet to find available sounds. Using a bear voice means that she knew that somewhere on the Internet would be the sound of a bear. From her statement about her choice of using a bear in her sound story

shows that MajaPaja appears to be knowledgeable in retrieving audio recordings.

Creation: MajaPaja’s sound story was only based on sounds or sound effects that are typical for a particular event in the story without using any words and any verbal comments. For example, when MajaPaja wanted to portray the presence of a horse, she could use a sound of horse neighing. When she has collected all necessary sounds for her story she edited and completed her story in special software for sound editing.

Reflection: On completion of her sound story, MajaPaja published it on YouTube; not only her sound-story but also another video in which she explains and describes how she did it. She then waits for people comment on what she has done.

To summarize, in the case of MajaPaja, creativity was to compose an original sound story without copying any known stories and findings ways to record sounds where she could not download sound effects from sound effect apps. Concerning autonomous learning, MajaPaja directed her project herself. She decided what story to tell with only using sound effects and she found her resources. She organized and created a sound story herself. This finding has affirmed McLoughlin and Lee’s (2010) argument of how autonomous learners direct their learning in online information settings.

Conclusions

In the future, the formal education seems not be more and more able to provide digital literacy development for people’s whole life. “The knowledge, skills and understanding we learn as children and as young people ... at school, during training and at college or university will not last a lifetime” (SEC (2000) 1832, 2000: 7).

Therefore, **everybody should care about his/her digital literacy development** throughout his/her life because new, more complex and advanced, technology will appear and the former one will disappear and what one learnt about technology before will not be enough for the future. Everybody’s life will depend more and more on a level of his/her digital literacy. “A

lack of digital literacy increasingly implicates one's full potential of being a competent student, an empowered employee or an engaged citizen." (Meyers et al. 2013: 355) Ability to managed autonomous learning and self-motivation will be "the driving force in lifelong learning, preparing students in schools for years to come. Students should be encouraged to take an active role in the learning process." (Syslo 2004: 102). Therefore, schools should concentrate on teaching pupils to learn how to learn.

Digital literacy could be developed out of school or in formal education but increasingly thanks **to sharing experiences** with others (schoolmates, friends, siblings, etc.), in personal (face-to-face) interactions or via an online social platform. For example, YouTube can support such exchange of experiences and contribute to digital literacy development based on autonomous learning, as Tan (2013: 463) showed in her research "how the students interacted with each other in these informal spaces and the role that YouTube video content plays in community formation and supporting informal peer learning."

Even though people are not advanced in some digital technologies, they should **not be afraid of using** them. The underlying aspect in their self-confidence to use new digital technologies could be (1) intrinsic motivation and (2) the feeling to produce something useful or interesting and share it with their family or friends or colleagues. For example, adults whose digital literacy skills are critical for being able to fully participate in a society and most of them may not fully engage in digital literacy skills development; nevertheless, some of them start to be motivated to use advanced digital technology when they need to communicate with their children or grandchildren (via e-mail or SKYPE) and to share digital materials (photos, videos, etc.) with their family or friends or to publish on the internet video-recording related to their hobby (mushroom picking, aviation, modelling, knitting, etc.).

An interesting problem or an idea of what to do can significantly contribute to digital literacy development although s/he is not enough digitally literate yet or s/he does not know what software

and hardware will need to solve the problem. A **strong motivation** to solve a problem or idea to create something unusual causes s/he will master very quickly to work with software and solve his/her problem in an original and creative way. S/he learns to install new software applications or hardware and to work with them. In many cases, such problems are multidisciplinary.

Even though, autonomous learning is considered to be learning by yourself, we can see that in many cases, learners receive **some facilitation and support** from their friends and family, and all these facilitation and support led them to be more autonomous in their learning. The example with MajaPaja's story demonstrates that autonomy in her learning is not just that she is searching for information from books or online resources but she also seeks advice from other people to expand her knowledge and digital skills.

The perspective of the concept of creativity is not only to create something unique but also to include digital technology to produce something that we have not thought before. It is important to have a good idea and not be afraid to deal with it. And this is what MajaPaja has demonstrated. Autonomous learners in a process of solving problem or creating interesting ideas can improve their digital literacy.

Cross-References

- [Digital Storytelling in Teaching and Research](#)
- [Exploratory Study Using Self-Regulated Self-Development \(SRSD\) and Technology in the Context of the Classroom](#)

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Digital Media

► Digital Storytelling, Information, and Education

Digital Media Boards in Primary Schools, Use of

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Synonyms

Digital noticeboard; Post-it board

Digital Media Boards

A digital media board (DMB) is an online, web-based tool that enables the collation, curation, and creation of digital artifacts. Accessing a DMB is straightforward, through a unique website address, which can be made public or private, depending on the intended use.

While there are an increasing number of DMBs available online, in education settings there appear to be two websites that are most popular. These are Padlet (www.padlet.com) and Lino.It (en.linoit.com).

Both tools offer similar basic functionality; however, Padlet appears to be more popular in primary schools, due its moderation and teacher-control settings.

A digital media board can be used to conduct a discussion, collaborate on a task, or collect images, videos, or documents in one place. It can also be used as a visual organizer with the flexibility to create individually or with others.

Potential Benefits of Digital Media Boards to Student Learning in Primary Schools

Several clear benefits to student learning can be identified through the educational use of digital media boards (DMBs).

DMBs are online platforms that enable students to have conversations around text-based questions, images, or videos in an *asynchronous* space. This means that discussions do not occur in real time, but instead can be added as students choose.

Classrooms, however, tend to be *synchronous* spaces. When questions are asked in the classroom, students who are confident of the answer will likely raise their hands. Teachers call on these students, while others look on, perhaps still pondering the question.

In an asynchronous space, students have time to reflect and focus on the question or problem. Students can also read the ideas of others to compare to their own beliefs and can then provide their contribution to the group.

DMBs are not always used asynchronously. Teachers may ask for immediate feedback from students while they, for example, watch an educational video. Using DMBs asynchronously, however, provides students with sufficient time to reflect and carefully construct their contribution, as a personal learning experience.

By enabling all students to have an opinion on a question or topic, DMBs provide a space in which no one voice is louder than others. These online spaces can be seen as equalizing students' voices and bringing the teacher into students' discussions. Alexander (2006 p. 6) has demonstrated that increasing students' ability to engage in the conversations and discussions of the classroom can have significant learning advantages. DMBs can support students and teachers to “transform classroom talk, increase pupil

engagement, and lift literacy standards from their current plateau” (Alexander 2006, p. 6).

Digital media boards are easy to access and to use, and this seems to have increased their popularity with teachers and students. DMBs, such as Padlet, are accessible on a wide range of Internet-connected devices, including laptops, tablets, and smartphones.

A teacher shares a link to their Padlet board with their students. Each student then opens the link and can immediately begin work. This ability to quickly bring students together online is crucial to lowering barriers to technology use in the classroom. DMBs are an example of easy to use and equitable technology resources. No matter the device, students can engage in the conversation at the same level as their peers. For schools in which bring your own device (BYOD) programs, or no technology programs, exist, this is a significant advantage of the digital media board.

DMBs enable the uploading of videos, images, and documents. Users can take photos using their mobile device and add them directly to the board. An example might be a small group project of students working to bring together a research report on the state of their local natural environment. As each member investigates and collects evidence and ideas, these are added to the DMB. On the DMB, a video of the local, polluted stream sits next to documents discovered on the local council’s environmental policy website. As the evidence is collected, each piece can be moved around the DMB to create categories. As the project grows, the categories can be easily rearranged or even deleted or merged. This flexibility positions students as leaders of their learning and encourages them to work collaboratively to develop an in-depth understanding of their topic.

The use of effective feedback in classrooms has been highlighted by much research in recent years, in particular by Hattie and Timperley (2007). From Hattie and Timperley’s (2007) meta-analyses, it was reported that formative assessment, which is undertaken to inform the next steps in learning and teaching, is a significant factor in improving students’ learning. A digital media board can facilitate the use of feedback in classrooms.

A simple DMB that either invites student feedback on a particular lesson or asks students to express their learning so far can offer teachers a better understanding to both of their teaching practice and their students’ learning progress. Teachers might use a single DMB for a learning domain that is added to over the course of a unit of study or school term. Alternatively, teachers might create individual DMBs to gain feedback on students’ comprehension of specific content areas, such as fractions or electricity or grammar usage. The ability for students to contribute multimedia to the DMB also supports them to express their learning in a range of ways, beyond traditional written methods.

Beginning with Digital Media Boards in the Primary Classroom

Designing a digital media board (DMB) is not complicated. Each DMB service does, but offers slightly different functionality and settings. These should be considered when choosing a platform for use in the classroom.

Four main factors should be considered when setting up a DMB:

Purpose

How will the DMB be used? If students access the DMB purely to read content or access a link, your choices will be different than if students will contribute to the DMB. Having a clear purpose, ideally attached to a learning outcome, will make the digital media board more useful and effective for teaching and learning.

Layout

Most DMBs will provide some layouts for participant contributions. Examples from Padlet (www.padlet.com) include:

- A list. A social media type layout where new posts appear at the top of a long vertical list of contributions.
- A wall. This layout automatically fits contributions together in an easy to read layout, much like a brick wall.

- A shelf. This layout enables the creator of the DMB to create columns with headings, under each of which specific questions, comments, or artifacts are posted.
- A canvas. This blank layout enables students to add content anywhere on the page. This is useful for categorizing or sorting activities where students might want to move items around on the page.

Access

Who will be using this DMB? Be clear about who will have access to write or contribute and who will have access only to view. Also, consider the public nature of the DMB. If it contains sensitive subjects, anonymous contributions might be most appropriate. If you wish for broader community contribution, the DMB might be open and searchable on the Internet. These settings are all configurable in Padlet and in Lino.It.

Ownership

Who will have access to create the DMB? Consider who is the principal author and how a teacher or adult supervisor might best support students' appropriate behavior online. Consider whether contributions should be moderated by an adult before appearing online.

Moderating, Managing, and Leading Digital Media Boards

While easy to use and quick to set up, teachers and students should reflect on their online safety practices in the DMB to be sure that they keep their identity and personal information private, despite interacting online. Three central concepts should be considered:

1. Students under 13 years old are not usually legally entitled to sign up for online resources. This means that if primary school students create accounts on DMBs, they may be breaching the terms and conditions of that resource. A safer, more appropriate approach

is to support younger students to engage with DMBs as a small group or whole class. Ideally, a DMB would be created by a teacher or supervising adult. Students can then add contributions to the board without requiring a user account or sign in details.

2. Teachers should investigate the moderation features of any DMBs they might use in their classrooms. This is important for modelling and teaching students about safely contributing to online spaces, particularly in the primary school years. If a student adds something inappropriate or off-topic, moderation features enable the teacher to amend or remove the item in question and have a learning conversation with the student.
3. Students should be supported to use pseudonyms or first names only in a DMB. As students contribute and engage with their peers, they need to recognize their fellow students, but they do not need to read their full names. Using a consistent pseudonym is important for working in the online space and helps hold students accountable for their actions.

Educational Uses for Digital Media Boards

A further useful feature of digital media boards (DMBs) is that students can engage with a range of multimedia resources in one online space, without losing time, or focus, transitioning between webpages and computer folders.

While layouts that include multimedia may initially appear chaotic, overlapping, multimedia board can be exactly what teachers intend when setting up DMB with multimedia. The teacher may seek for each student to contribute, in whatever format they choose, which could then be used to drive a whole-class discussion and investigation. Knowing that their individual contribution would be discussed by their classmates may have the additional bonus of bringing all students into the discussion as eager participants.

Students and teachers may also use a DMB feature called "Remake" to recreate a copy of a

board, using a board as a template to build their own version. In this way, students can move, append, or delete contributions without destroying their initial board.

Teachers may also choose to include comments on the DMB. This is a further feature of DMBs. By enabling contributors to comment on the Padlet, the original author does not have their contribution changed or deleted. Instead, others comment underneath the original item and offer advice or suggestions. This can provide an ongoing sense of ownership for students as they focus on the feedback they receive and can respond.

As students engage with their peers online in a DMB, they also have opportunities to practice appropriate digital literacies and digital behaviors in a safe, moderated space. It can be a challenge to provide primary school students with online practice spaces to rehearse these skills, as concerns about abuse and safety might arise. Students at ages 10–12 have been shown in Australia (Australian Bureau of Statistics 2016) to be engaging in digital technologies and social media at a high and increasing rate. A digital media board, moderated by a teacher or supervising adult, can offer a rehearsal space for students as they begin to engage in wider social media websites and a range of online interactions.

There are numerous ways to use DMBs in the primary classroom; the examples in the following section provide suggestions for further uses, based on teachers' experiences in the classroom.

Ideas for Digital Media Board Use in the Primary Classroom

A digital media board can be either a one-way, teacher-directed repository of learning resources or a two-way collaboratively created space. The DMBs shared in this section provide authentic examples of boards used in the primary school, with a brief description of potential uses in the primary school classroom.

A basic example of a DMB is a board created by a teacher to bring together a range of resources.

Resources are gathered on the page under general headings to support students in accessing the correct item. Student of this type of DMB cannot move items around or add comments. The links to web-based resources are live enabling students to jump in and out of the DMB as they need. Using a DMB in this way enables the teacher to provide students with a single website address. From this address, a large number of other resources can be accessed.

The background images in Padlet and Lino.It can be easily modified. This means any image can be set as the background, on to which students then post their contributions. For example, a teacher might set an image of an erupting volcano as the background. The teacher then sets up the DMB but allows students to add labels to it, demonstrating their knowledge of the topic.

Sometimes teachers choose to enable anonymous contributions so that students can contribute to a DMB without fear of being wrong and having their errors exposed to their classmates. Using the "Canvas" template in Padlet, the teacher led a whole-class discussion on the accuracy of each label and moved them as necessary.

Enabling the voice of each student to be heard in classroom discussions, the DMB can be set up to structure the conversation around specific questions or themes. A teacher can develop a DMB that frames students' discussions around key concepts or known challenges in a specific topic.

Students first add a response to a concept or question and then build on the work of others, by commenting and explaining their thinking.

Conclusion

Digital media boards are easy to use online resources that are accessible on all Internet-connected devices. These digital boards are web-based and can be customized in numerous ways to meet teachers' and students' learning needs. Whether created by students or teachers, digital media boards provide students with

opportunities to understand and deeply engage in their learning.

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Digital Methods

- [Problem-Based Learning Online](#)

Digital Narratives

- [Digital Storytelling, Information, and Education](#)

Digital Noticeboard

- [Digital Media Boards in Primary Schools, Use of](#)

Digital Object Library

- [Institutional Repositories Versus Learning Object Repositories, Challenges and the Way Forward for Higher Educational Institutions](#)

Digital Portfolios

- [Capturing Learning Through Mobile Device Cameras](#)

Digital Simulations in Healthcare Education

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Synonyms

[Computer-based simulation](#); [Screen-based simulator](#); [Simulation games, and serious games](#); [Virtual patient cases](#); [Virtual patient simulation](#); [Virtual patient](#); [Virtual reality simulation](#); [Web-based simulation](#)

Introduction

Patient care requires strong expertise and professional competence. As self-care increases, patients are being admitted to hospitals with increasingly complex problems. It has commonly been reported that as many as 1 in 10 hospitalized patients are harmed while receiving care, and approximately 43 million patient safety incidences occur every year. These cause great human suffering, but their economic impact is also high; for example, medication errors cost an estimated 42 billion USD annually (WHO 2017).

The World Health Organization (2017) has emphasized patient safety as the most important measure of quality of care. Ensuring patient safety is a fundamental ethical requirement for healthcare professionals. One of the greatest challenges facing healthcare today is to deliver effective and evidence-based care in challenging and rapidly changing situations. A majority of the deaths that occur in acute or general hospitals are related to a wide range of diagnostic errors, unrecognized or unattended patient deterioration, and resuscitation issues following cardiac arrest (Soar et al. 2015). Training and skills development is one of the recommended actions for enhancing patient safety in regard to these issues. The management of such situations requires, in addition to professional skills, continuous maintenance of competence.

The ability to manage critical situations should also be regularly demonstrated. Simulation pedagogy is ideally suited for this purpose since it enables active, experiential, situated, and problem-based learning. Simulations are situations that replicate actual or probable real-life conditions or events. Traditionally, in healthcare education, simulation-based learning has been delivered in classrooms or simulation centers. Recent technological developments have made it possible to provide simulations in digital environments. Modern technology can be used to immerse and engage learners in meaningful and motivating learning experiences. Furthermore, educational organizations need to deliver deeper, active learning experiences and skill-based training that integrate technology and can be accessed anytime and anywhere (Horizon Report 2017). Digital simulations commonly focus on problem-solving, and the ability to solve clinical problems is among the core competencies of healthcare professionals. Interactive and immersive 3D simulations can be seen as facilitators of virtual experiences (de Freitas 2007); and in healthcare education and professional development, learning is often experiential in nature. In order to emphasize the current era of digitalization, this article discusses the use of digital simulations in healthcare education.

The term *digital simulation* is used in this article to refer to artifacts (software and/or hardware) that replicate decision-making processes in real-world situations through different technologies, such as mobile devices, simulators, haptic simulators, games, virtual reality, augmented reality, and mixed reality. In the following sections, the benefits of healthcare digital simulations are discussed. First, different simulation technologies used in healthcare education are described. Second, the utilization of gamification in simulations is discussed. Third, motivational aspects and psychological and behavioral outcomes of digital simulations are described from the point of view of healthcare education.

Healthcare Digital Simulations

Simulation-based learning has established its place in healthcare education at universities and

hospitals over the past two decades. It is well suited for learning clinical skills, clinical reasoning, critical thinking, collaboration, leadership, and teamwork. Simulation has a positive impact on learners' knowledge, confidence, competence, and self-efficacy (Cant and Cooper 2017). Simulation as a learning strategy has been defined as "a dynamic process involving the creation of a hypothetical opportunity that incorporates an authentic representation of reality, facilitates active student engagement and integrates the complexities of practical and theoretical learning with opportunity for repetition, feedback, evaluation and reflection" (Bland et al. 2011, 668). This definition is similar to that given by Gaba (2004, i2), who wrote "simulation is a technique, not a technology, to replace or amplify real experiences with guided experiences, often immersive in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion." The key challenge for effective learning with digital simulations is for the learner to be both engaged and motivated. For learning to be effective in digital environments, a connection must be made between what is learned and how such learning is applied in practice (de Freitas 2007). The benefit of digital simulations is that they are virtual fields of practice providing learners with opportunities for problem-solving, skill performance, and competence assessment in a controlled setting.

Technologies relevant for simulations have been divided into three types: mannequin-based simulators, screen-based simulators, and virtual reality simulators (Gaba 2007). In the healthcare literature, a large number of concepts are used in relation to digital simulations: e.g., "screen-based simulator," "computer-based simulation," "web-based simulation," "virtual patient," "virtual reality simulation," "virtual patient cases," "virtual patient simulation," "simulation games," and "serious games." Common to all of these terms is that they model a real-world situation using computers, mobile devices, virtual reality systems, or simulators. Learning methods that reproduce reality allow healthcare students and professionals to practice and learn the key competence of their profession in an immersive and

engaging way. This is because, in these systems, the patient and/or environment are presented to the learner through two- or three-dimensional visual and audio representations.

Most computer-based simulations in healthcare are low-fidelity, text-based scenarios that have been supplemented with images and/or videos (e.g., Forsberg et al. 2011). They can be, for example, video clips of actors portraying patients in a hospital setting (e.g., Verkuyl et al. 2017). Recently, serious games have been increasingly used to support professional learning and competence development, while simulation games dominate the field of healthcare. Simulation games refer to artifacts (software) that replicate decision-making processes in 3D, high-fidelity, real-world situations. Simulation games combine simulations and game elements (see Koivisto et al. 2018). Especially in medicine, simulators and haptic simulators have long been used to develop surgical skills, such as in laparoscopic surgery. Haptic simulators recreate the sense of touch and create a more immersive learning experience. At present, virtual reality (VR) is emerging alongside computer simulations. VR is “a computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors” (Oxford Dictionary). The benefit of VR over computer-based simulation is that in the former, immersion is more powerful and the learner has the opportunity to totally become a part of the real patient situation. Immersion refers to learners’ experience of being drawn into the virtual world such that they feel or perceive themselves to be part of the environment. Immersion and active participation in patient care create mental models for the learner that are useful in real-life situations. Another new technology emerging in the healthcare sector is augmented reality (AR), which “is a technology that superimposes a computer-generated image on a user’s view of the real world, thus providing a composite view” (Oxford dictionary). AR has been implemented in several healthcare areas, such as laparoscopic surgery, administration of

local anesthesia, endotracheal intubation, clinical breast examination, and life-support training (Zhu et al. 2014). Mixed reality (MR) is a mix of VR and AR. VR, AR, and MR are “visualization technologies which use a brain’s inherent ability to process visual information rapidly, identify patterns, and sense order in complex situations” (Horizon Report 2017, 37).

The challenge of forming an overall picture of the current situation of training applications in healthcare is that in the literature, the terms games, simulators, haptic simulators, VR, AR, or MR are used either inaccurately or synonymously. In addition, the face, content, construct, and predictive validity of studies related to different platforms are often poorly assessed (see Arora et al. 2014), which makes it difficult to evaluate the actual benefits of certain platforms for learning outcomes. Regardless, technologies with educational applications already exist, but the challenge lies in the content: There is not yet enough learning content to integrate, especially VR and AR, sufficiently into curricula. From the point of view of patient safety, it is important that the content is evidence-based and consistent with clinical protocols. Furthermore, as stated in the Horizon Report (2017), technology and digital tools can be ineffective or even dangerous when they are not integrated into the learning process in meaningful ways. One concern is the possible drift toward technology rather than pedagogy (Bland et al. 2011); advancements in technology and educators’ enthusiasm in adopting them may displace the use of learning theories and pedagogy. Another barrier might be the complexity of new technology and equipment, which could discourage educators from using technology-enhanced learning environments. Another barrier might be trainers’ ability to manage complex new technology and equipment, which may decrease the willingness of educators to use technology-enhanced learning environments. One important factor is financial resources: At present, universities are struggling with low financial resources, and thus the benefits of every new educational method and technology are measured precisely before investing in it. However, looking to the near future, when enough quality content exists,

games, simulators, VR, and AR have the potential to become significant learning methods alongside other methods; indeed, they could even replace more traditional methods. For example, in the future, substantial resource-dependent classroom simulations could be replaced by virtual simulations conducted at learners' homes.

Gamifying Healthcare Digital Simulations

The phenomenon of gamification is pervasive, affecting media, commerce, workplaces, research, education, and health, to mention just a few. Gamification refers to the application of game design elements and game principles in nongame contexts (Huotari and Hamari 2012). Gamification is also increasingly being represented in the area of healthcare. Gamification has been exploited, for example, in health promotion, prevention, early diagnosis, therapy, and rehabilitation. However, the challenge related to gamified applications in the area of healthcare is that their benefits for clinical outcomes might not meet expectations (see Edwards et al. 2016). For example, Laver et al. (2011) found no evidence that the use of virtual reality and interactive video gaming was more beneficial than conventional therapy approaches in improving stroke patients' upper limb function.

Games and gamification are also increasingly used in professional training in healthcare. One of the reasons why gamification has been utilized in professional training is the ability of games to engage learners in the learning process. Engagement in learning is highest when concentration, interest, and enjoyment occur at the same time (Hamari et al. 2016), and learners' engagement in the learning experience can be strengthened by adding game-like features to digital simulations. For example, nursing students have expressed that in order to provide significant learning experiences, educational games need to share some of the characteristics of leisure games, such as visual authenticity, immersion, interactive 3D environments, high-quality animation and sound, and immediate, sustained, and delayed feedback

(Koivisto et al. 2018). In an educational context, it is very important to integrate specified learning goals, conflicts, rules, interactions, and challenges into game characteristics (Hamari et al. 2014). Being engaged and immersed in a game depends on how challenging it is and how skilled one is at playing it (Hamari et al. 2016). The benefit of combining games and simulations is that games can provide scenarios far more complex than those in laboratory simulations (Petit dit Dariel et al. 2013), which can in turn challenge learners to the limits of their skills. Challenging tasks enable knowledge construction (Kiili et al. 2012), while game challenges can strongly predict learning outcomes (Hamari et al. 2016). Learning is most effective when the difficulty level of the tasks and the learner's skills are in balance.

Digital simulations can benefit all learners. Studies, however, have yielded somewhat contradictory results with respect to who benefits most: those who have more experience with virtual worlds or games or those who have no previous experience. Koivisto et al. (2016a) found that nursing students who were heavy or occasional digital game players felt that they learned better clinical reasoning skills than those who did not usually play at all. Similarly, Rosser et al. (2007) found a link between video game playing and laparoscopic surgical skills and suturing skills: They found that video game skills and past video game experience (consisting of at least 3 h of play per week) had a significant impact on laparoscopic skills. Video game players make fewer mistakes and perform faster than non-players. These outcomes may be explained by the fact that those who play have more experience reading the signs of the game system than those who do not play. However, prior experience of gaming may have negative impacts on learning with digital simulations since regular gamers have high expectations for fidelity and interaction, which may be poor in virtual worlds. Additionally, if the virtual environment is unstructured and open-ended, regular gamers who are used to structured and goal-oriented activities might find it difficult to navigate (de Freitas et al. 2010). This interpretation is slightly different from that of Arora et al. (2014), who argued that the more

junior the participants are, the more likely it is that training using virtual reality models will improve their knowledge and skills.

Therefore, gamification can be thought to have positive effects on learning outcomes and thus also on patient safety and quality of care. But what is the mechanism that produces positive learning outcomes when gamification is added to digital simulations? According to Hamari et al. (2014), gamification has three main parts: (1) the implemented motivational affordances, (2) the resulting psychological outcomes, and (3) the further behavioral outcomes. The motivational affordance categories can include points, leader boards, achievements/badges, levels, story/theme, clear goals, feedback, rewards, progress, and/or challenges. Psychological outcomes often relate to motivation, attitude, and enjoyment. Behavioral outcomes in the learning context relate to learning outcomes, such as achieving learning goals, task performance, and effectiveness of learning. In the following sections, motivational affordances and psychological and behavioral outcomes are reflected from the point of view of healthcare digital simulations.

Motivational Aspects of Healthcare Digital Simulations

Digital simulations have the potential to raise learners' interest in the learning content in many ways. Learners must experience the simulation as useful for their own professional competence development. This fact is highlighted in the Horizon Report (2017), which states that real-world skills are needed to improve employment and workplace development. Learning environments in which learners can practice key competences of their profession can promote learner self-directedness toward learning material and self-motivation. Motivation psychologists Ryan and Deci (2000) stated that when three innate psychological needs – competence, autonomy, and relatedness – are satisfied, self-motivation is enhanced. They distinguished two types of motivation: intrinsic and extrinsic. Intrinsic motivation refers to doing an activity for its own sake, for the

inherent satisfaction it generates. In contrast, extrinsic motivation refers to the performance of an activity in order to attain some external outcome. In the healthcare sector, job satisfaction is often derived from the ability and competence to help patients. Thus, the motivation to perform the job well is usually intrinsic rather than extrinsic. This same motivation should be cultivated in learning, and therefore learning opportunities that mimic reality should be promoted in healthcare education.

One motivating factor is likely to be that in the area of healthcare, most digital simulation applications simulate real-life clinical situations and patients' clinical conditions. Simulations consist of patient scenarios, or stories, which are events designed around a specific clinical situation. The learner usually assumes the role of a doctor, nurse, or some other professional. The authenticity and reliability of patient scenarios are important when considering the educational value of a simulation (Koivisto et al. 2018; Forsberg et al. 2011; LeFlore et al. 2012). Solving patient scenarios requires clinical reasoning skills, which constitute an essential competency for healthcare professionals. Clinical reasoning is a logical, dynamic, and ongoing process that includes the following phases: collecting and processing information, identifying problems and issues, establishing goals, taking action, and evaluating outcomes (Lewett-Jones et al. 2010). Clinical competence is a key element in safe patient care; accordingly, healthcare professionals are expected to show a high degree of competence in clinical reasoning and must be able to use it efficiently to make decisions, often independently, in complex situations (see WHO 2017).

Another motivating factor is that digital simulations have clear goals, which often include the development of clinical reasoning skills. In digital simulations, learners develop their clinical reasoning skills through different clinical situations and patient conditions (e.g., heart disease patients in emergency departments or palliative care in hospice). Clinical reasoning requires the ability to think critically, to prioritize, and to follow treatment protocols, which in turn requires that the learning objectives and game mechanics are

integrated in such a way that the simulation replicates real clinical reasoning processes (Koivisto et al. 2018). During simulation, learners should find relevant information related to the patient's clinical condition, determine the specific nature of the patient's problem, and then treat the patient correctly. The challenge in digital simulations is that patient scenarios often require learners to use their previous theoretical knowledge and experience in patient care in order to successfully solve the scenario (Koivisto et al. 2016b).

The most obvious motivating factor in healthcare digital simulations is that they can create authentic patient-related experiences (Koivisto et al. 2018). The authenticity of patient scenarios requires realistic and challenging clinical conditions. Real-life experiences can be supported by authentic audiovisual representation. Authentic representation of clinical practice can be created by using 3D characters in a 3D environment representing the hospital ward or other healthcare setting, with authentic behavior by virtual patients and interactive medical equipment. A patient's clinical condition and any changes can be observed with the help of animations, such as patient movements, facial expressions, and gestures. Authentic sounds suggesting patients' clinical conditions direct the learner to the patient's problem, helping to prioritize actions. Another important issue regarding immersion is that digital simulations should allow the learners to interact with the patients and the hospital environment. Interactivity refers to the interaction between the learner and the virtual environment, and it enables players to see the consequences of their actions. The more effectively the interaction is enabled, the more realistic and engaging the learning experience will be. The same scenarios can be shared using various technologies, and the level of immersion will vary depending on the device used. For example, VR is more immersive than simulation games played with a browser on a computer. Immersion can be diminished if patient scenarios are not realistic, virtual patients are not lifelike, or the scenarios lack interaction. This can in turn undermine the achievement of the learning objectives and can at worst cause frustration and boredom among learners.

The special benefit of interactive high-fidelity digital simulations is that they raise and sustain motivation. One study found that even though the performance level in a simulation game group and text-based cases group was the same, the simulation game enhanced students' motivation considerably, was perceived as more complex, and stimulated students to put more effort into the cases when compared to the text-based cases students (Dankbaar et al. 2016). Learners' motivation toward digital simulation can be promoted by enabling learners to actively experiment by considering different choices and making decisions in relation to the patient's clinical condition. Working with virtual cases increases learners' self-confidence in solving clinical problems (Forsberg et al. 2011), as they are able to explore, try out different strategies, make mistakes safely, learn by trial and error, and test their competence (Koivisto et al. 2018). Thus, learners become more confident in their skills and competencies. Motivation can be added by setting time pressures and limiting permitted errors: Performing a scenario against a time limit forces learners to practice quick decision-making. This skill is required especially in acute care and in rapidly changing situations. Additionally, the scenarios can be repeated, which helps learners to internalize and automatize clinical procedures and protocols. Altogether, these factors show that the option to practice patient care by using hypothetical scenarios increases patient safety. Digital simulations also increase learners' inner sense of security because they can learn from mistakes without harming real patients (Koivisto et al. 2018; Foronda et al. 2016).

To benefit fully from digital simulation, real-time feedback on a learner's performance is necessary. The timing of the feedback is important (Botezatu et al. 2010): Learners especially favor immediate feedback on their performance (Koivisto et al. 2018). If feedback is provided only at the end of the learning situation, it may be too late. In this instance, learners cannot effectively connect the feedback with their actions. However, it is necessary to *also* receive feedback at the end of the scenario, as doing so allows learners to consider issues of cause and effect

and combine their experiences with their knowledge of patient care. To gain deeper knowledge rather than learning only from memory, getting reasoning, especially with regard to errors made during the scenario, is important. To trigger reflection on learning and personal development, digital simulations should provide immediate, sustained, and delayed feedback. Koivisto et al. (2018) reported the following feedback systems in healthcare simulation games: (1) Types of immediate feedback include correcting errors, scoring, patient reactions, in-game facilitator's comments, and the effects of success and failure; (2) sustained feedback refers to changes in patients' clinical conditions during gaming, the accumulation of scores, and documentation of players' choices in the log; and (3) delayed feedback refers to players' total scores and a description of correct performance. In another study by Buttussi et al. (2013), the game gave feedback by informing the learner about the errors made and the current patient's state, summarizing the situation and providing hints for self-correction. These abovementioned feedback systems enable learners to track their competency development, which, in turn, increases the learner's intrinsic motivation to practice more to gain the knowledge and skills needed in real patient situations.

Psychological and Behavioral Outcomes in Healthcare Digital Simulations

The use of digital simulations in healthcare education has many positive psychological outcomes and other positive effects on students' learning. Healthcare students have experienced virtual simulations to be engaging and motivating (Benedict et al. 2013; Verkuyl et al. 2017). For example, a 3D single-player serious game designed to refresh trainees' advanced life-support knowledge and decision-making skills positively engaged and motivated participants in the scenarios (Buttussi et al. 2013). Similarly, a computer-based simulation increased satisfaction among nurses in setting priorities and implementing nursing skills as a protocol (Roh et al. 2013). Students also value

digital simulations because working with cases independently prior to face-to-face lessons supports students in becoming more self-directed learners (Benedict et al. 2013). In addition, learners value working at their own pace. Individually completed digital simulations offer all learners the same learning opportunities as opposed to classroom simulation, where only some of the learners are active actors in the exercise.

One benefit of using virtual reality is that it can be an efficient method for reducing student anxiety since it provides opportunities to repeat an exercise as many times as needed to achieve an adequate level of competence. However, Cobbett and Snelgrove-Clarke (2016) found contrasting results. They found that anxiety scores were higher for students who participated in the virtual clinical simulation than for those who took part in the face-to-face simulation. Positive learning outcomes have been found when intravenous (IV) simulators incorporating virtual reality (VR)/haptic device technologies were used for practical exercises of intravenous injection (Jung et al. 2012). The simulator used haptic devices that provided a sense of resistance during venipuncture and realistic 3D photographic images via polarized glasses. The skin and vein of intravenous (IV) simulators were displayed on the monitor. Likewise, Verkuyl et al. (2017) found that similar learning outcomes were achieved in relation to knowledge, self-efficacy, and satisfaction when virtual gaming simulations were compared with traditional laboratory simulations. However, the best learning outcomes are often achieved when digital simulations are used in parallel with traditional hands-on laboratory simulation (Cook et al. 2012; Jung et al. 2012; Verkuyl et al. 2017).

Mostly, digital simulations have been used for learning cognitive skills, clinical management skills, interpersonal skills, and clinical reasoning skills (Koivisto et al. 2016a; Petit dit Dariel et al. 2013). A study conducted by Evans et al. (2015) showed that playing a mobile-accessible, case-based, online game improved pregraduate and postgraduate medical learners' knowledge in recognizing and managing sepsis. Another

study revealed that a serious game with realistic, interactive cases improved residents' complex cognitive skills but was not as effective for inexperienced medical students (Dankbaar 2017). Further, when measured objectively and when using self-assessment before training, game-playing residents have shown improved clinical competencies in emergency skills compared with residents who only read course material. However, after a 2-week training period, this advantage disappeared (Dankbaar et al. 2017).

In digital simulations, a systematic approach to following the phases of the clinical reasoning process can help students to learn clinical reasoning because simulation games provide opportunities for learning by requiring students to act and think while solving the scenarios. In simulation, the activities of collecting information and taking action require concrete actions, such as clicking the mouse when collecting information by interviewing, observing, and measuring patient data, as well as taking action by implementing nursing interventions. The activities of processing information, identifying problems and issues, establishing goals, and evaluating outcomes, on the other hand, require thinking. One of the reasons why digital simulations can be recommended for use in healthcare is their potential to exert a greater impact on knowledge retention, knowledge acquisition, and knowledge application than traditional learning methods (Botezatu et al. 2010; LeFlore et al. 2012).

Digital simulations are effective tools for gaining and maintaining skills, which is especially important in the context of life support. These skills have a significant impact on patient safety, and it is recommended that life-support skills should be practiced regularly; perhaps this is why life-support applications have been the most developed. Good learning outcomes have been achieved by using the simulation gaming platform to undertake immediate life-support training. Gaming has enhanced learners' knowledge, psychomotor skills, and decision-making skills (Cook et al. 2012). Gamified simulations can also improve healthcare students' cardiopulmonary resuscitation knowledge and skills. In

one resuscitation game, the storyline revolves around an emergency situation, represented in a 3D virtual environment, where the victim, the helper, and all the helper tools may be required in the emergency. The learner takes the role of the helper, and the mission is to save the victim by applying cardiopulmonary resuscitation actions in the correct way to obtain the maximum score. Students who used the game achieved significantly better learning acquisition scores than those following traditional classes; in addition, they performed the cardiopulmonary resuscitation protocol better (Boada et al. 2015). Similarly, a 3D serious game proved to be effective in knowledge and skills acquisition in advanced life support as well as in the retention of acquired knowledge and skills at 3 months (Buttussi et al. 2013). In that game, learners had to perform various examinations (e.g., check for pulse or monitor vital signs), communications (e.g., elicit symptoms or medical history), and treatment tasks (e.g., ask a teammate to use a defibrillator). To succeed in the game, learners had to choose appropriate tasks among several alternatives in a sequence recommended by advanced life-support guidelines.

Conclusion

All the evidence described in this article supports digital simulations as a valuable learning method for healthcare education. They can therefore be recommended for use in healthcare education alongside other methods and, in some situations, may even replace traditional methods. Implementation of digital simulations in curricula is at an early stage in universities and vocational schools. However, digital simulations are especially valuable for improving patient safety insofar as they can improve healthcare staff competence in identifying patients at risk of cardiac arrest or other severe adverse events in hospitals. Digital simulations could be incorporated as part of regular staff education but could also be used by everyday citizens to help others in need and thereby prevent suffering, loss, and disability.

Cross-References

- [Game-Based Learning](#)
- [Games in Higher Education](#)
- [Games, Simulations, Immersive Environments, and Emerging Technologies](#)
- [Gamification](#)
- [Learning with Simulations in Healthcare](#)

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Digital Storytelling

- Digital Technologies and Literacy Contexts for Young Indigenous Children

Digital Storytelling in Teaching and Research

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Synonyms

Metaphor; Narrative; Pedagogy/pedagogical purposes; Qualitative research; Visual method

Introduction

The aim of this entry is to present digital storytelling as teaching and research method and draw from findings of previous studies in order to offer an updated definition based on both essential dimensions, the activity of telling stories and the use of digital technologies. Toward this end, the term will be considered as a metaphorical noun phrase. Words can be identified as metaphors at the level of language when they display a contrast between a target domain meaning and a more basic source domain meaning; also, at the level of thought, when they display a contrast between concepts that belong to different conceptual domains; and finally, at the level of communication, when they are used as metaphors to indicate a change of perspective of the target domain of an utterance. In all these cases, a contrast or comparison is involved in metaphorical meaning. More particularly, the metaphorical twist in the noun phrase “digital storytelling” lies in the ways stories have been communicated, orally or in writing, in juxtaposition with stories communicated with the use of digital technologies. Despite the contrast, the use of technology for storytelling is nowadays popularized and, therefore, conventionalized. As a result, the metaphor is conventional as well. However, the co-text also matters, since where, why, and how a metaphor is used determine the level of novelty and the degree it constitutes an innovative use of language.

The sense descriptions of “education” in the dictionary (Oxford), for example, hardly relate the field with storytelling, despite the fact that this is a domain where stories are told on a daily basis. In this context, storytelling becomes part of a broader scenario. Within this context, storytelling in education for pedagogical and research purposes could be considered as novel metaphor. Here are two examples to illustrate potential metaphorical sense of storytelling for educational purposes.

In education, storytelling with digital technologies in schools creates a hybrid context that opens up the space for action and meaning-making for students and teachers. Within this context, learning opportunities come up both “unplanned”

and as outcomes of guided formal instruction, thus transcending conventional classroom boundaries. This way of integration of digital storytelling in education introduces informal elements contrary to the formal disciplinary tradition and offers an opportunity for communicative engagement in web-based settings where exchanges can both converge with and diverge from instructional norms. Such integration has, therefore, a non-conventional character.

In research, digital storytelling is a visual method that brings to the fore and reconstructs the narratives of the research through the analysis of the message, underlying structures and techniques, how this is conveyed to audiences, and what channels of communication are used. Considering that the focus of educational technology research is mainly on how tools are used in teaching and learning, such a shift toward the discussion and analysis of the communicative integration of technologies in the classroom indicates another nonconventional use of digital storytelling.

Considering these possible ways of application, it becomes evident that both parts of the noun phrase play a role in what different significations of digital storytelling can be.

Digital Storytelling as a Twenty-First Century Metaphor

This extended entry will draw from contemporary metaphor theory (Reijnierse 2017; Steen 2011) in order to explicate the meaning of the term, based on applications in education that use digital storytelling to frame teaching and research. To this end, I will discuss digital storytelling as a phrase where the noun (storytelling) is used metaphorically and is modified by the adjective (digital) that designates the target domain of the utterance. According to metaphor theorists (e.g., Lakoff 1993; Lakoff and Johnson 1980; Ricoeur 1978; Steen 2011), a metaphor occurs when we talk about something by means of something else and, therefore, a stretch or twist is required for sense making. This metaphorical twist involves a movement to a target domain (in this case: telling

stories) to explain what, for instance, technologically enhanced practices in the field actually mean nowadays. In this sense, “digital storytelling” is a twenty-first-century metaphor that signifies mapping of two domain areas in the meaning-making process. In this mapping, “digital” signals the comparison between the domain of technology and that of telling stories.

The sense descriptions of “storytelling” in the dictionary (Oxford) involve both traditional and contemporary notions of telling or writing stories. These descriptions point to the medium, or the channel, used to communicate the story, with illustrative examples that refer to the hero/character as an integral feature of tales, myths, and legends, and also personal narratives, political commentaries, and evolving cultural norms through mainly visual technologies. The meaning of storytelling, therefore, although metaphorical, is quite conventional, if we consider the general scope of its meaning. And yet, looking into storytelling as a whole whose parts are inscribed in different modes and, as a result, mediate the communicative event with different means changes the perspective on the metaphor and the degree of its novelty.

In oral storytelling, the communicative event involves a dialogue between a speaker and a hearer, where something is expressed and communicated to another (Kaplan 2003: 30). This is a shared dialogical experience for mutual understanding and reciprocal recognition. To this effect, the speaker produces an experience for the hearer in which the latter recognizes the intention of the former. This means that to understand the meaning of the dialogue is the same as to understand what the speaker means. To resolve misunderstandings, the speaker and the hearer can ask each other questions.

In written storytelling, the story takes a life of its own, as the meaning is no longer dependent on the co-presence of speaker and hearer. In this way, the story must be interpreted in the absence of a speaking subject or a shared dialogical situation that acts as common reference. Therefore, the meaning of the author and the meaning of the written story may or may not coincide. The difference here is that while the shared dialogue

mediates oral storytelling, it is the different forms of emplotment that mediate written storytelling. We will therefore need to consider the narrative dimension of written expression.

In a similar way, digital storytelling involves multiple modes of expression through language and other symbols and media. However, contrary to traditional visual and cinematic storytelling, digital technologies have offered the possibility for interactive ways of telling stories online through the use of web-based platforms and internet services.

A contemporary definition of digital storytelling should take into account these dimensions. In addition, if we consider storytelling to be an essential feature of education, the perspective changes. As the sense descriptions in the dictionary do not connect the words with each other, storytelling for teaching and research purposes has the potential to constitute a novel metaphor for the field of education.

In the following sections, dimensions of such novelty will be discussed.

The Narrative Dimension of Storytelling with Digital Technologies

To this end, Ricoeur’s narrative theory (Ricoeur 1978, 1992; Kaplan 2003) will be used as framework to validate the definition of the term by looking into digital storytelling as series of actions organized for pedagogical and research purposes.

Classroom Interaction as a Meaningful Whole

Education has long been characterized by sets of practices that assign the central role to the teacher and the task to orchestrate the classroom event and be the protagonist on the pedagogical stage, the basic decision maker, and handler of the bulk of talking time. Looking at the metaphor anew, if by storytelling we refer to practices that change the good old script, then the term acquires a novel meaning. The content of learning, for instance, is set by the specifications of the curriculum that the teacher has to put into practice with pedagogical means. While the teacher can choose from a repertoire of methods and techniques, the

frameworks set by the curriculum leave a restricted space for teachers to truly author the pedagogical scenario, especially nowadays when the need for standardization becomes more and more marked. As a result, the teacher's agentic action becomes limited (Eteläpelto et al. 2015). Moreover, as the use of digital technologies is part of such standardization, it is doubtful whether their integration into classroom practices constitutes a novel experience in the school. And yet, the teachers' pedagogical purposes do not only draw from the official script. They are also informed from other domains such as wider socio-political developments (Vivitsou [in press](#)), which opens up the space for teachers to contribute as essential authors of the narrative in education and develop agentic action.

As it is the case with every narrative, the story of the classroom should consist of a number of events organized in a unified whole. Digital storytelling constitutes one case of holistic approach. As such, it requires the organization of sets of tasks and activities, being the parts (or events), so that the advancement of the narrative can be achieved in a meaningful way.

One way to put the events of the story together in order to construct a meaningful plot would require recounting of the involved agents' (i.e., the teachers' and the students') actions. As a result, bringing together the agents' goals and means is needed for classroom pedagogy where all agents are contributors. Within this context, teachers and students become co-authors in digital storytelling. As actions develop, the agents develop as well. It is therefore the development of both agents that needs to be accounted for.

Such development occurs in dialogue, through the co-ordination of social (e.g., group work), symbolic (e.g., a myth), and material (e.g., mobile devices, software) tools. Dialogical practices reflect the view of development as a dynamic space of reciprocal meaning-making interaction (Macy 2016; Moll and Whitmore 1993; Thompson 2013; Zaretskii 2009). Within such learning environments, development is achieved recursively as assisted performance aiming for artifact construction. As Mariotti (2009) argues, constructing artifacts enables learners to both

build shared meanings and relate with personal understandings. In this way, the process is reciprocal and takes place at the inter- and intrapersonal level. Nowadays, the view that development can happen in interaction with a knowledgeable other is disputed. Not only can the young learner learn from the teacher and peers, but teachers can learn from their young students by observing how tasks and activities are performed, decisions are reached, meanings negotiated, and so on. While development is common for all the agents, it is purposefulness that makes it relevant.

Furthermore, it is interaction on the course of dialogical situations that makes development meaningful. In digital storytelling, dialogical situations involve face-to-face communication in the classroom where the co-presence of students and teachers is required. Such communication involves both a teacher-to-student and a student-to-student pattern. In addition to the classroom, it can also occur outside the school in natural or informal settings. In these cases, the communication event takes place in dialogue or in writing and corresponds to oral and written storytelling, which was mentioned in the previous section.

Furthermore, communication can be asynchronous, when taking place on the internet through a web-based platform or service. While in the first case language is the main mode of exchange, in the second communication it is achieved through a computer and with multimodal ways of expression. As the digital media facilitate the use of technologies of transcription, modes such as speech, moving and still image, and writing appear and are available for use. In this sense, digital stories are expressions of multimodal design (Kress 2011). As such, digital stories are themselves parts of digital storytelling and use multiple modes to make the meanings of events tangible, or, according to Kress (2011), to realize or materialize meanings.

The fact that meaning is multimodal has implications both in the way it is produced and communicated. On the one hand, the production process impacts the organizational and the material setting of the classroom. On the other hand, basic parameters of the communicative event shift toward new directions, from real-life to virtual

settings, from spoken language used for oral communication to written language used for oral communication, and so on. This means that the boundaries of what is spoken and what is written blur. Therefore, different types of choice are required for meaning production and interpretation and, naturally, not all choices are relevant. The way, for instance, a response to a question is structured in face-to-face communication does not follow exactly the same rules as a response to a question on a social network, where punctuation and emoticons are essential to make up for the absence of gestures and other body language. Linguistic expression therefore remains relevant, only in different ways. As a result, these shifts open up the space for a whole new array of topical areas to be considered in education.

One such area concerns choice itself and, to be exact, what constitutes the best choice. It is therefore timely to rethink what critical judgment means and how to achieve it in education. Choice does not apply to the linguistic domain only. Also, it presupposes the act of interpretation, which, in turn, presupposes a degree of critical thinking of how to both interpret the problem and get to its solution, and evaluate its relevance to a certain kind of reality. Choice therefore relates to the context where critical judgment is exercised. Although critical judgment is essential, it is not self-evident. Rather, it should be one primary pedagogical goal aiming to support development in relation to what the learners' needs are, as these are defined within their own reality. As choice is task-based, it depends on the task as well. The more the task is bound to subject matter, the more it applies to the reality introduced by the curriculum. On the contrary, the more the task is shaped on the basis of real-life needs, the more communicative it becomes and the closer to the learner's reality it gets.

This entry aims to define digital storytelling as a metaphor in education. To this end, it will draw from research projects of pedagogical integration of digital technologies in order to lead to sense descriptions of the term based on a discussion and analysis of the tasks around which the whole experience was organized. The tasks themselves signify the events being the parts of the whole of

the digital storytelling narrative. These relate to the actions of both teachers and students, being the agents of digital storytelling. Thus, the development of events is a correlate of task development, which, in turn, links with the development of agents. Such development is performance-based, aims for communication, and involves the use of competence in several domains. As this account focuses on the whole experience, pedagogical implementations, applications, and products (e.g., the digital stories) are examined as the inside parts, or co-text, of the digital storytelling "text." In addition, "outside" elements (e.g., who the participants are, where from, and so on), or context, are taken into account. Therefore, both co-text and context are important for a valid and reliable explanation of metaphors. To be more accurate, in this case co-text and context overlap.

Storytelling as a Metaphor in Education

The co-text is, therefore, important to the way we attach meanings and determine the degree of metaphorical novelty of terms. In contemporary metaphor theory (e.g., Steen 2011), novel metaphors add an external perspective to the target domain of the utterance, in the sense that they indicate meanings different from what used to be the norm. These are called deliberate metaphors and, in terms of communication, indicate a perspective-changing function of meaning (Reijniere 2017; Steen 2011). If, for instance, storytelling is used to refer to practices that shift the discourse in education, in terms of the ways teaching is delivered and research is conducted, with the "characters" involved taking on agentic roles, then this sense constitutes a deliberate metaphor. Considering the whole noun phrase, "digital" makes more explicit the target domain of the noun it modifies and, as such, constitutes a domain adjective.

The domain adjective can work as signal of a new metaphor or as disambiguator of meaning (Reijniere 2017). In the first case, this would mean that the noun (i.e., storytelling) of the adjectival phrase (i.e., digital storytelling) would always point to the field of education. This, however, is highly improbable. Therefore, only the second function is possible in "digital storytelling." This means that "digital" further specifies

the target meaning, contrasts with oral and written, and expands the notion of storytelling. This is a more generalized use of the term and is to some degree applied here to indicate the different communication channels for telling stories.

However, this entry will focus on the function as conventional metaphor signal that revitalizes the metaphorical meaning of the noun. In this case, the noun is a potentially deliberate metaphor. To further illustrate this point, Reijnierse (2017) offers examples of multiple metaphorical propositions where more than one lexical units are metaphor-related words. In “rebuilding governmental machine” and “throws a spanner on the Whitehall machinery,” for instance, the function of the adjectives is not novel per se. But the overall context signifies a revitalization of the metaphorical use of the noun (machine). In such cases, the adjectives work as signals of the revitalized metaphors and the nouns are identified as potentially deliberate metaphors. In a similar way, this entry will draw from empirical research on digital storytelling for pedagogical purposes and principles from narrative theory in order to discuss and analyze the innovative dimensions of the metaphor noun storytelling and bring forward digital as a practice that has the potential, not only to disambiguate between means but also revitalize contemporary education.

Digital Storytelling for Pedagogical and Research Purposes

The Research Projects: Background and Methods

In the studies discussed in this entry, multiple technologies are used systematically to create a unified and coordinated learning-for-engagement with fun experience by combining and dispersing integral elements of a fiction across multiple web-based, digital, connective channels. The digital story is one in which separate elements of a larger narrative can be experienced by different audiences through a range of technological platforms. In addition, digital storytelling draws from learner-centered approaches aiming to enable student learning through the use of connective

technologies, digital mobile devices, and language toward the production of meaningful outcomes (McGee 2015). The aim is to give students a chance to tell their own stories about the topic under discussion, highlight participatory practices, increase engagement on the topic, sustain collaborative efforts, and encourage shared learning and creativity (e.g., Lambert 2013; McGee 2015; Niemi et al. 2014; Woodhouse 2008).

The studies build on the Global Sharing Pedagogy model introduced by Niemi and Multisilta (2016) to provide a framework for learner-driven knowledge and skill building by working with peers, networking and developing digital media competences and literacies.

For research purposes, the studies involve surveys, field notes, observations, and interview data resulting from the international projects that were organized and coordinated by the University of Helsinki, between 2012 and 2014. During that period, 12–15-year-old students from Finland, Greece, and California, and later, China (2015–2016) were involved in making and sharing digital stories with peers across classrooms and countries on a web-based environment. These young people, therefore, being speakers of different languages, were in intercultural encounters online. Digital storytelling activities combined formal and informal settings, while the use of English emerged as a need to tell the story to international audiences of peers when sharing on a web-based platform. Thus, they transcended the boundaries of the classroom. To deal with the situation, the students turned to available resources, including friends, class, subject and English teachers, parents, dictionaries, and the Internet. This use of language is evidence of the young people’s agency and reflects the desire to sustain the intercultural dialogue online. At the same time, it uncovers the need to further understand the complexity of using language to communicate when social and digital technologies are involved.

For the analysis, both qualitative and quantitative methods were used. Qualitative methods were applied on students’ and teachers’ interviews, the scripts of the digital stories, and the comments the students offered on the web-based environment. During the interviews, the students’ perspectives

came forward as well as how they looked at themselves not only as students but as computer and language users as well. Also, the teachers' beliefs and attitudes about the reasoning underlying their pedagogical decisions and choices came to the fore. To analyze the data, different ways of content analysis were used (e.g., thematic and metaphor analysis) for patterns underlying the participants' speech to be traced and valid conclusions to be reached. Quantitative methods aimed to show trends in participation and measure the level of student engagement. In this way, a multi-dimensional, in-depth understanding of the digital storytelling process was aimed for.

Within this framework, Niemi and Multisilta (2016) found that technology promotes engagement and allows for student-generated stories to come up (Niemi and Multisilta 2016; Niemi et al. 2014). Student stories recount single or multiple events, while the types of stories vary depending on the background teaching approach (Vivitsou et al. 2016).

Development Through Interaction and Communication

To make digital storytelling work, the teachers introduce the use of a web-based platform to connect students across classrooms. This indicates an orientation to practices that favor blended learning in school communities through interaction and online participation. As this is a dynamic, newly introduced experience in schools, it does not only require proper connectivity and infrastructure, but also takes a comprehensive view of learning with digital technologies and entails time and effort, and different types of organization and support. Therefore, different types of action are required.

Constructing Professionalism in Action

Using web-based platforms for pedagogical purposes opens up a whole array for activities and collaborative work that aim to both structure and problematize the digital storytelling process and support student work (Vivitsou et al. 2017). This type of support is determined when the teachers plan the classroom work and design the course of

action. The complexity of digital storytelling, however, does not allow for every single major or minor decision to be made in advance or every single detail to be predicted. The teaching plan, thus, is more fluid than static and, thus, rather than predefined, teaching practices develop in-action here. This means that the teachers construct professional knowledge in-action, as while observing students performing tasks, they modify their earlier decisions. In this sense, digital storytelling is a dynamic developmental experience for teachers as well, as it allows for emergent and, thus, recursive (Kvale and Brinkmann 2009) practices in situ. Recursive practices match the current needs for flexible and adaptive teaching to guide and support students adequately through the complexities of the digital era. It also serves the need for agentic action.

In an era when the digital technologies are greatly favored by the media, the market and educational policy, whether their integration into the classroom practices is a manifestation of agency, is debatable. Eteläpelto et al. (2015), for instance, claim that although notions of autonomy and professionalism have guided education in Finland for decades, new systems of governance and monitoring, reporting, and evaluation move the profession toward more limited possibilities to practice agency. Therefore, if professional agency still exists, it should be traced in the ways technology is used in combination with the pedagogical practices, in the ways the work of teachers advances.

Supporting Student Group Work

In the digital storytelling case where students need support to manage hard learning, tasks that both structure and problematize the process are needed (Vivitsou et al. 2017). The former aim to reduce complexity by, for instance, distributing the work to groups, asking students leading questions, teaching how to edit a video, and so on. The later aim to allow students to raise questions and think deeper about the process and the content. A great deal of support is needed during class work.

To this end, the teachers introduce a range of social (e.g., group work), symbolic (e.g., a myth), and material (e.g., mobile devices, software)

tools. Such practices reflect the view of student development as dynamic space of reciprocal meaning-making interaction (Macy 2016; Moll and Whitmore 1993; Thompson 2013; Zaretskii 2009) where development is achieved recursively as performance aiming for artifact construction. As Mariotti (2009) argues, constructing artifacts enables students to both build shared meanings and relate with personal understandings. In this way, development is reciprocal and takes place at the inter- and the intra-personal level. Moreover, as they evaluate own and peers' digital stories in groups, the students develop oral, written, and digital literacies while they exchange with peers, solve problems together, give and get feedback about their strategies, and adapt them when needed. In this way, students engage actively for deeper learning.

In all schools, the teachers set up digital storytelling activities in informal settings. These include topic-related places such as a museum, the local open market, the school yard, an island to study a natural phenomenon, as well as the home. In terms of knowledge creation and skill development, student background knowledge is a significant aspect of organizing digital storytelling work. Organizing digital storytelling activities in informal (natural and technological) environments allows students to investigate the phenomenon in situ, do research with internet-based sources, and decide what aspects of the topic to study, what pictures to take, how to put them together, and so on. In this learning environment, students have choice, as they work with tasks that open up opportunities for making decisions and solving problems in interaction with peers.

In addition to devices and applications, teachers combine a wide range of tasks and activities to shoot photos and videos, and edit them with mobile cameras, cell phones, and tablets. In this way, they develop digital literacies and skills, for instance, when material devices (i.e., hardware and applications) are used for digital story creation, while both a "bring your own" and a "use the school's" approach are applied. Overall, teachers handle technical requirements and perform a seamless introduction of digital tools into the classroom with a balanced use of older and

newer technologies. However, the main purpose here is to structure the process of storytelling (Vivitsou et al. 2017), rather than raise questions about, for instance, the digital divide. Despite the fact that the multiple stages of the process and the complexity of tasks (Wass and Golding 2014) open up the space for such problematizing to occur, assistance is given priority over actual development.

Problematizing the Process

Although it is structuring the work that seems to be favored, the teachers' decisions indicate a turn toward problematizing the established school reality. One way toward this direction is the integration of principles from diverse disciplines to teach content and a movement away from a "teaching-the-subject-matter" orientation to a "guiding-for-development" approach in natural surroundings and informal settings (Vivitsou et al. 2016, 2017). In addition to rethinking of the classroom as the only viable option, the collaborative mode of work is a work pattern that is preferred by teachers in all digital storytelling classrooms across countries. Collaborative work can reduce task complexity and get the activity going, as well as cater for development through peer interaction for evaluation, negotiation of the content of the story, its structure, and so on. Therefore, it offers choice for students to work on aspects and areas that they would like to, and allows for personalized learning. As well, the teachers can observe classroom action and reflect on own decisions. In this way, collaboration is one step to take their thinking further and weigh between the need for structure and critical judgment.

In addition to common approaches and characteristics, it seems that there have been choices that can potentially mark unique teaching styles able to move the profession toward more concrete agentic action, as a counteract to the loss of autonomy the "new public management culture" has invoked (Eteläpelto et al. 2015) on the grounds of tightened accountability. To further illustrate this point, three examples will be mentioned here from the digital storytelling situation (Vivitsou et al. 2017).

One concerns a mid-career male Finnish teacher who explains when interviewed that his intention is to build a narrative and draw connections between the past and the present. More particularly, the aim to allow the students to explore what the Ice Age has influenced the evolution of the Finnish landscape and, in this way, gets a deeper understanding of history through geography in field trips and observations and a freer way to learn. A second example is about an experienced female Finnish teacher who defines herself as a constructivist and, as such, committed to finding ways that allow students to draw connections for knowledge building. For this purpose, she chooses storytelling as one way to make students' thinking visible. She does so, like a "magician in a theatre or a circus," always in search for something new. A third example concerns a female mid-career teacher from Finland who believes that the classroom needs to open up and expand its boundaries, especially now when the school becomes more and more multicultural. Intercultural encounters, therefore, using digital storytelling as teaching method seems to be a pathway for her students from diverse backgrounds getting motivated and engaged with learning. Moreover, digital storytelling is one way to collaborative practices that make schooling more democratic and less authoritative.

Although more research is needed on the matter, these choices point toward particular styles of teaching that, at the time of the digital storytelling implementation, made teaching a singular, individual work. Partnering with methods and techniques that give more choice and more voice to the student, individual stances to historically grounded teaching aiming to bring the young people's thinking to the fore through freer schooling may form the basis for bottom-up practices for a restored agency in the profession. Thus, singular, theoretically grounded choices combined with universal approaches mark the teachers' orientation in digital storytelling.

Performing Multimodal Storytelling Tasks

As we look into digital storytelling as narrative, how the classroom events develop matters. Therefore, the students' actions and how they achieve

meaning construction plays a role. In digital storytelling, meaning is made through a multiplicity of modes that present evidence of learning in different ways. Under this lens, learning results out of the engagement with an aspect of the world that is the focus of attention on-task, on the basis of the principles the individual brings to that engagement. Such engagement is thus leading to a transformation of the individual's conceptual resources (Kress 2011). Conceptual resources include both a better understanding of the object of study (i.e., the content or subject matter) and an updated sense of identity. Initiative plays a crucial role in this development.

Student Initiative

The studies discussed here show that the students developed initiative for mainly two purposes. One type of initiative emerges out of group and individual work aiming for story completion and task accomplishment (Vivitsou et al. 2016, 2017). In order to make the stories communicable, the young people turned to friends, teachers, parents, and the Internet for language and other types of support. In this way, they were able to subtitle, structure, publish, share, and comment the stories. In this way, the stories are not only testimonies of the young people's taking action, but also of the desire to sustain the dialogue in group work and with connected peers online.

While developing a sense of being storytellers, students enter a dialogue with peers where cultural characteristics show up, as, for example, when Greek student stories reveal elements that connect the historical past with the present, by drawing upon mythology and history. In this learning space, students develop an embodied rather than exclusively cognitive appreciation and display an ability to respond with new initiatives. In this sense, the students do not just carry out, but perform the task. Thus, commitment to hard work seems to be intertwined with performance. This becomes obvious through mainly three ways of student action:

By taking on a role and acting as director, script writer, narrator, and so on, student appreciation of the story-making process changes.

By entering into dialogue with peers, they act with rather than acting over others.

By acting to explore and understand better, student appreciation of the surrounding space and those found in it as well as of the process and the content of learning changes.

They also re-establish relationships with peers and develop a sense of being-in-the-world by getting involved with other people, other species, and the surrounding space, whether physical or virtual. In this sense, students do not simply enact a preassigned role, but learn and grow by changing through own efforts and encourage others to change as well (Vivitsou and Viitanen 2015). Ultimately, student initiative, embodied action, and ongoing decision making, although not in a mutually exclusive way, are related.

Intercultural Exchanges with Peers Online

Within this context, the use of English as common medium comes up “unplanned” rather than as outcome of guided formal instruction to transcend conventional boundaries. This opens up the opportunity for learners to use diverse texts from “out-of-school” domains and, thus, pushes the boundaries of formal schooling to get unsettled at the intersection of the “script” (i.e., the curriculum) with the digitally mediated lifeworld contexts (Lund 2006; Ørevik 2015). In this sense, digital storytelling is a generative device that proceeds from practice and work toward the production of artifacts and works of discourse. In other words, digital storytelling constitutes a (pedagogical) genre (Vivitsou 2016) that encompasses the ways of acting and the purposes of those who act. In terms of communicative purpose, digital stories can generate cross-cutting text types, ranging from descriptive to expository to narrative to dialogic and reflective (Ørevik 2015).

As the findings of the empirical studies show, student-generated stories can be single- or multiple-event based when they tell the story of one or several instances or aspects of a phenomenon (e.g., a historical event, a chemical reaction, etc.). When they tell the story of the young story makers’ everydayness, the stories are student-

initiated (Vivitsou et al. 2016). Both event-based and student-initiated stories use language to pass the message through. Language use mainly comes up in the form of oral expression in the speakers’ L1 (mother language) and can be preplanned (e.g., as in the case of event-based stories) or more spontaneous (e.g., in student-initiated stories). It can also come up as written speech in the shape of, for instance, subtitles (or annotations, i.e., short verbal explanations of the content of the story). Subtitles aim to summarize and provide the gist (i.e., the main idea) of the story.

Use of Language for Authentic Purposes

As students share digital stories with peers on a web-based environment, storytelling activates discussions and exchanges in the form of comments. Such interactions can offer insights into the content, the production or the purpose underlying the story, and can offer the ground for deeper reflection on these areas. The aim here is both to set and expand social relationships, and meet the pedagogical purposes.

Storytelling by using web-based platforms and the services of Web 2.0 involves social networking practices. When, for example, the young people share stories online and respond to their peers’ comments in the designated area of a web-based platform, they type capitals and post emoticons to signify gesture and other body language markers. In this way, while interaction turns become enriched through comments (Penttilä et al. 2016), semiotic markers make up for the absence of other signs of communication and introduce a contemporary popular practice into the classroom event. Emoticons are not the only symbolic system.

The story itself is based on signs and symbols, in terms of the ways storytellers represent the events, and how the characters express themselves. The young people, as mentioned above, use their L1 to communicate the message of the story. In addition, they need to use a language other than their L1, in order to share and communicate with international peers. Language can come up in the form of oral expression and can be preplanned or more spontaneous. It can also come up in the form of subtitles to summarize and

provide the main idea so that the story can make sense.

In this way, the young people are engaged in symbolic work in multiple ways. In digital storytelling, symbolic work concerns both text-based and video-based exchanges. It is, therefore, essential that future practices will consider the need to set a common “language” that does not involve the linguistic code only.

Furthermore, it becomes clear that when the young people work on the story, they already have the distant peers in mind. The distant peers are imagined. According to Norton and Toohey (2011), imagined communities can represent a reality as strong as that of learners’ daily engagement, and can have an intense impact on the learning process. Norton (2010) even argues that a lack of awareness of learners’ imagined communities could narrow the possibilities of development in that learning environment.

Identity scholars (e.g., Norton 2010; Norton and Toohey 2011; Pavlenko and Norton 2007) link imagined communities with the learners’ imagined identities, as the one assumes the other. As Norton and Toohey (2011) argue, a target (language) community is not only a reconstruction of past experiences and historically reconstituted relationships. It is a desired community offering a range of identity options and a way for learners to look to the future. Nowadays, web-enhanced encounters in multilingual settings make even more pronounced the need to consider how young people construct identities, as the fluid time-space and the lack of boundaries of the electronic medium can create ambiguities of subject positions (Kramsch 2009: 172–173).

The computer, therefore, is a window that looks through and at the world, and, as such, frames reality through the symbolic forms that appear on the screen. As a result, the young students are nowadays engaged with identity work, as they author and narrate their pathways to their audiences by using computers and digital technologies. According to Thorne and Black (2011), as diverse language-cultural backgrounds of participants intersect in heterogeneous textual inspirations, participants are engaged in symbolic work by actively contributing to a transcultural blend of

literary and popular culture fictional worlds. In this way, members of the community enter a process of interpreting one another’s work, while they author their narratives sitting behind the screens of their computers or navigating through the screens of their mobile devices.

Digital Stories for Pedagogical Purposes

When it comes to digital storytelling tasks, it is not only the digital story that matters, it is also the “about the story” or meta-story that should be taken into account. Attributing meta-features contextualizes the story and extends the digital narrative. In this sense, the digital story is part of the whole of digital storytelling, not the whole per se. Following this, the following section will focus on issues about the stories. One such issue concerns the different sets of events that the digital stories can present. Some stories focus on instances of the object of study and others present more complex plots. While the former act like zoom-in lenses of the classroom narrative, the latter build up networks of actions. In both cases, the students act as storytellers and characters. The characters of the stories can be real or fictional. As a result, different types of stories come up.

The types of digital stories (Vivitsou et al. 2016) relate to the underlying teaching approach and are categorized into: (1) subject-based digital stories, (2) interdisciplinary digital stories, and (3) student-initiated stories. The latter had an indirect connection to curricula, introducing themes and events that were interesting and important to students. The topic and perspective in subject-based stories focus mainly on a school subject, whereas interdisciplinary digital stories cross these borders. Following this initial categorization, the digital stories are reviewed from the perspective of narrative: on one end of this scale, there are stories that describe student observations on instances of a phenomenon; on the other, the stories are longer and demonstrate a tighter narrative structure.

Subject-Matter-Focused Stories

Instances of a Phenomenon These subject-specific stories present the students’ efforts to capture a particular aspect of a phenomenon, in this case a

chemical or physical one, in order to study and obtain a deeper insight into it. The production of these stories varied from rather unedited video clips to more structured ones, yet the key attribute was that they consisted only of a single scene that had been captured at once. These clips were about tasks carried out during lessons or events observed on field trips. In a sense, they were captured “in the heat of the moment” in order to document what the students considered relevant and interesting.

The possibility of filming seemed to increase student motivation when science learning was transferred to off-school sites (e.g., field trips, a chemistry laboratory, science center, etc.). In the lab, students could focus on and observe experiments very attentively through video lenses. Selecting a phenomenon and trying to understand and explain the event (e.g., a chemical reaction) to a potential audience were important parts in the students’ study process. In some cases, subject-based stories were recorded at home or during a holiday trip. When conditions permitted, stories were filmed in classroom settings (e.g., the science lab).

Multiple Phenomena-Based Stories These include clearly distinguishable clips that together form the story. In this way, they build a tighter narrative than the aforementioned instance-based stories. One of the most elaborate multiple phenomena-based digital stories about science was related to air and was captured on a field trip. This story combined different themes, which mainly enriched the curricular content taught at school. The storyteller also put significant effort in structuring and framing the scenes with relevant scientific explanations in the form of annotations (i.e., a type of subtitles that can be added during the editing process for further explanation or descriptions of the object of study). The story grouped different air-related exhibitions into four scenes. The first scene consisted of a short video clip of a scale model of Earth. The second portrayed a student testing the effects of air pressure with a pump-like device, where a weight is dropped inside a tube in order to achieve a causal effect in a tube placed next to it. As a result of

dropping the weight, a tennis ball flew up in the other tube. The third clip dealt with a hot air balloon that rose and fell. The final scene was captured during a live performance where a scientist demonstrated the space requirements of gases by inserting a straw into subliming dry ice.

Interdisciplinary Digital Stories

Most of these were multievent stories. As a single event, a story could be a picture or snapshot of the single phenomenon, e.g., a video clip from a forest. In interdisciplinary stories, the attention is placed on a series of actions. Therefore, the plot displays a more elaborate structure by, for example, introducing a conflict or reaching a climax and resolution. Interdisciplinary stories cross the borders of different subjects for production. For example, stories about myths were created during history and Greek language lessons. Overall, they build a tighter narrative and introduce fictional characters. The multievent stories focused on the following themes.

Themes from the Human Sciences These stories build a more structured narrative by recounting multiple events in the characters’ lives using dramatization (e.g., body movements and gestures) and other narration techniques to support storytelling. One example draws upon ancient Greek mythology to provide alternative versions of myths. A secondary aim is to enhance student understanding of a natural phenomenon such as season alternation during the year by drawing links with mythical explanations from ancient times.

In the story *Euro, the birth of Europe*, two narrators support action with scripts delivering the message to the international network of peers using English subtitles. Dramatization techniques are efforts to free the communication of meaning from language barriers. The storyline centers on three main characters: Zeus, Europe, and the people. In another story, the *Myth of Persephone*, oral narration pulls plot strings together and the 8-year-old storyteller alternates text slides with action to support the narrative. This filmic practice not only mimics silent movie logic, but also aims to overcome language barriers arising from the

fact that the students have just been introduced to learning the English language.

Combining Complex Themes Some digital stories presented variations of a more complex phenomenon, such as recycling. To produce the videos, the students worked together to create a plot and convey the message through the interaction in the story. Unlike the myths, these stories introduce “real-life” characters using several filmic practices. In this classroom, the students decided what kind of stories they would like to produce and what aspect of recycling they would like to explore in their videos. All stories aimed to inform and give instructions about how to recycle and, in general, were dramatized and acted. In some of these videos, one character does not know how to recycle and another advises to do that. Alternatively, a character seeks information on ways of recycling from the Internet. Some stories were more documentary-like, where filmmakers showed how recycling can be done in an authentic place.

In contrast to the subject-based stories discussed above, interdisciplinary stories are produced at the end of a series of lessons. While in subject-based stories the students used annotations to offer explanations, the students added subtitles to the theme-based stories on recycling in the postproduction phase. In both cases, they did so in order to pass the message to international peers online. In addition, some stories were performed in English.

Hanging Out

So far, digital stories have a close relationship with themes grounded in curricular requirements. In these cases, the teacher’s initiative is often primary. However, not all stories are based on teacher initiative to put forward a topic for student work. Some build on student initiative and aim to present a theme that projects, for example, instances of home life and culture or their hobbies. In this respect, digital storytelling relates to the formal content of learning both directly and indirectly and requires both aspects of engagement, as fun and as commitment to hard work, in order to produce meaningful outcomes. As these also

provide evidences of how these young people relate and hang out in their free time, they constitute an authentic way developing different types of competence and literacies.

In the following examples, the students put forward their own ideas and filmed digital stories aiming to introduce themselves to peers, present instances of their lives and culture, and tell stories about who they are and what their day-to-day life is like during school or after school hours. These are deviations from the original teacher plan for curriculum-based digital storytelling and are, therefore, student-driven in terms of themes and production mode. The products could be single- or multi-event stories but, in most cases, they focused on a series of events.

Telling the Story of Who We Are Stories that deal with self-presentations are descriptive with videos that use a static camera and mainly long shots. Self-presentations can serve as pedagogical icebreakers and are produced within the school timetable. Overall, the filmic practice seeks to give a picture of the class as a whole. However, in the *A few things about us* story, filmic practice shifts the focus of presentation away from the long shot class view to groups of students presenting themselves. This is the English version of introductions that students publish in order to address the international audience a month after posting the Greek version. This story not only shifts the focus of attention to the group level, but it also evidences how student digital skills have advanced as they can now put together a series of clips to come up with a remixed version of the story.

The *local museum* is an example of a story produced as part of flexible zone activities. Flexible activities in Greek primary schools are part of the school timetable but, unlike subject-matter-oriented teaching, are project-based and thus interdisciplinary in nature. As with the myths, thematic and filmic student choices allow for a longer, more complex narrative to take shape. The *museum* contrasts the fictional character of the *myths*. However, the students’ effort to construct a plot to hold the narrative together is evident.

Background music is used here to create a sense of reverence and respect for the past.

Telling Stories in After-School Hours The students tell stories about their hobbies during their free time. In one of these videos, a female student tells a story about riding and taking care of her horse. The story, filmed at a horse farm, documents the process of grooming, taking care of the horse, and a demonstration of riding equipment and offers some advice on how to keep the horse. Long shots alternate close-ups. Tracking shots following the horse transport the viewer into the scene and add to the truthfulness of the story.

The message seems to be clear: this is a story of young people who care about nature and non-human beings. In addition, as the students take care to make the subthemes of the main topic explicit, this story belongs to the multiple- rather than the single-event type. Similarly, in a digital story about computing and playing computer games, the main character (a male student) presents the kind of computer he has and gives tips to beginner and experienced gamers. The video includes both long shots of the student's room and close-ups of the computer. Clearly, technology is the subject here. The camera follows the human character, and at some point, close-ups reveal the internal part, the anatomy of the computer. At the end of the video, four male filmmakers apply the screenshot technique showing their faces to tell the audience who the video makers are. In this way, faces replace end titles.

Overall, the tighter to the curriculum the stories are, the less space is left for interpretive action. In subject-based stories, for example, the students test a chemical reaction. In terms of narrative theory (Kaplan 2003: 52–53), the students perform a configurative operation that mediates a preunderstanding and a postunderstanding of the chemical phenomenon. The narrative arc is narrow here, while the reality the students refer to is the textbook reality. A lot more co-text is thus needed for this event to offer something other than sticking to the formal interpretation of what knowledge is. In comparison, the configuration of action in interdisciplinary stories creates

possibilities for an array of new meanings from a diverse narrative arc. Within this framework, the notion of digital literacy becomes increasingly vague. A multidimensional approach to digital literacy aiming for communicative competence is therefore needed.

A Contemporary Metaphorical Definition of Digital Storytelling

Considering the above discussion and analysis, storytelling online with digital technologies can be overall seen as one expression of computer-mediated communication that opens up the space for nonunitary, nonfinite digital literacies and promotes reflective ways of using technologies as well as the context of use. Nonfinite digital literacies are dynamic, embedded in everyday life as social practice, and fit better with the current need to develop a critical understanding of digital media (Buckingham 2015; Engen et al. 2015; Lankshear and Knobel 2015). This view is linked with agency gained at the click of the mouse, while the computer and multimedia technology both manipulate and recreate reality (Murray 1997). Given the needs of the digital era, in order to be able to tell what is fake and what is true, it is not enough to be competent computer user. It is not enough for schools to educate competent computer users either. Users should be agentic, taught by agentic teachers aiming for communication. This view of agency in relation to a dynamic approach to digital literacy opens up the space for analytical modes of research for deeper understanding, a shift of perspective in pedagogy including structure and critical judgment, and a space for endless storytelling that the narrative perspective in education opens up.

Concluding, this paper draws from findings of empirical research, metaphor theory, and narrative theory in order to offer a holistic view of digital storytelling not only as a method where digital technologies are introduced into classrooms, but as a metaphor that has the potential to revitalize the sense descriptions of education in terms of how teaching is practiced, and research is designed and implemented.

Within this perspective, teaching supports interaction within formal and informal settings, aims for communicative purposes, and allows for agentic action for both teachers and students. In this way, on the one hand, teaching takes the form of professional action with singular, individual, and universal characteristics. On the other hand, learning becomes a process where students develop content knowledge and build identities as computer users and as language users. In order to match with these purposes, research should aim to explain and attain an in-depth understanding of the process and the participants and, therefore, should be looked at as both historical and empirical reality. In this way, researchers can gain a narrative understanding of the research by placing the focus on the whole as well as the parts of the study, and by embedding digital literacy as part of a wider communicative competence.

Cross-References

- Digital Storytelling, Information, and Education
- Teacher Education, Thinking About ICT

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Digital Storytelling, Information, and Education

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“Don’t limit a child to your own learning, for he was born in another time”

Rabindranath Tagore

Synonyms

Digital media; Digital narratives; Media production; Video

Introduction

Ever since the computer was contemplated as a learning device in the 1980s (Taylor 1980), adults have debated whether children’s access to technology in schools is essential or that the technology is merely a distraction from the real learning. It seems remarkable that almost 40 years after technology for learning purposes became viable, the significant use of these technologies can still be considered as peripheral. Even though children might use devices ubiquitously in their out-of-school lives, it is possible that they may still spend much of their school day reading handwritten text from a whiteboard, writing on paper with a pencil or pen, and using paper-based worksheets and notebooks. While they are probably using computers or mobile devices, this might be in limited ways: to “look up” information and to “type up” written work or for drill and practice, in the form of educational activities or games. This is an unacceptable scenario. The twenty-first century has been designated as “The Digital Age,” and the children of today will rely on digital technologies extensively throughout their lives. It is essential then that they learn to use digital tools effectively, understand how technologies work and can employ the technologies for their own purposes.

Fortunately, this realization has been growing over the last decade, and most school curriculums

now incorporate a component that relates to the use of computers, information technologies, and digital learning. For example, in the Australian curriculum, this is called digital technologies, and it has two strands: digital technologies knowledge and understanding and digital technologies processes and production skills (ACARA 2018). While this learning area typically encompasses a wide range of predicable content including knowing how computers work and using and working with data and the ethical implications of using technologies, a significant part of this curriculum is allocated to digital design. This focus requires learners to imagine digital solutions, engage with problem-solving cycles and computational thinking, design interfaces, manage projects to completion, and then implement their product. The new curriculum direction is certainly exciting and holds promise for learners to be empowered to truly engage with digital technologies, rather than simply functioning as a user, without any depth of understanding.

As this new approach to using technologies comes to fruition, there are a number of challenges that teachers face. In particular, the concept of “digital design” has widely been assumed to mean computer programming, and therefore, teachers are expected to teach “coding” to all children, even from an early age (Brewster 2015). This is demanding for teachers who do not consider themselves to be computer programmers, and perhaps this is restricted interpretation of digital design which is unnecessarily narrow.

While computer coding is a very important part of digital transformations, it certainly isn’t the only skill that will be required to advance digital technologies in the future (Scott 2015).

Learning to write code builds computational thinking, but this can also be developed through a range of activity where logic, persistence, and creativity are required. Further, a digital project needs much more than coding to be realized. It is important to recognize that a wide range of skills are required for digital development and society needs people with different expertise in order to work in teams to implement digital solutions. Rather than expecting every teacher to teach programming, a variety of digital design activities could be considered to address the key objectives

of the curriculum. This entry suggests that “digital storytelling” can offer an opportunity for children to engage in the intricacies of digital design while at the same time learning important digital technology skills and concepts.

Digital Storytelling

“Digital storytelling” is a process where the storyteller uses digital tools to create a media production about their life, the place where they belong or some other aspect that is important or relevant to them. The concept of digital storytelling is linked to the tradition of oral storytelling and it developed in the 1990s (Ohler 2013), when digital tools became available and affordable to the wider population. Educators quickly connected with this genre, and it has become a popular mechanism to engage children in learning.

An advantage of using digital storytelling for teaching and learning is that it develops new literacies. Lankshear and Knobel (2008) suggested the term “digital literacies” and identified that this category encompassed a wide range of skills, techniques, and approaches for using digital technologies to create and communicate. Sylvester and Greenidge (2009) found that digital storytelling could be used to support children who were struggling with traditional literacy and especially writing. Children were more motivated to create stories when they could communicate ideas with audio and image instead of relying solely on text.

During the process of crafting their story, these children had plenty of opportunity to revise their work, and consequently their stories became more sophisticated than if they had simply followed a traditional writing process. Digital storytelling also supports collaborative literacies where children can work together on a production (Nordmark and Milrad 2012). In this process, children learn the skills of media communication in a social way, through negotiation and reciprocal sense making.

Another feature of digital storytelling is that it gives individuals the permission to voice a story that is uniquely their own. The process is highly individualized, and therefore, it is essential that the storytellers are empowered to build their own

representation rather than being prescribed a formula for construction. This, however, doesn't mean that the teacher is redundant in the process. In fact, Ohler (2013) suggests that the opposite is more likely, with the student needing careful guidance and advice throughout the production. In this situation, the teacher uses scaffolding (Masters 2008) to work with the storyteller to provide just-in-time support, as the children plan and work through their project.

Digital storytelling provides a contextualized environment for children to apply digital tools. As they work through their project, they will identify features that will require digital solutions. They might need record video footage with a smart phone or a GoPro camera, use recording software to create a voice-over, or use animation software to blend drawn images with video footage. If they are using mobile devices, they might need to engage in "app smashing" (Kulowiec 2013) where they need to use a variety of apps in sequence in order to complete their digital resource. The applied context means that children learn how to use the app or device for authentic purposes.

The "messy" nature of digital storytelling provides an ideal environment to help children develop digital problem-solving skills. Although digital storytelling doesn't require children to write computer code, there are plenty of parallels. The children need to be able to imagine the end result and then use a top-down approach to break the problem into manageable parts. They then need to plan the design sequence and work through steps and decisions to reach their end goal. They will also need to consistently engage in problem-solving cycles where they identify their problem, look at options, decide on actions, and then evaluate the outcome: a classic "see, plan, do, check" model (Polya 1945).

Digital storytelling projects are sometimes seen as a "soft" option for teaching about digital design, but it actually is a complex process that engages learners at high levels for an extended period of time. This does not mean that we no longer need to teach computer programming in schools, but it does mean that teachers who incorporate this activity in their teaching program can meet many of the goals from digital technologies curriculum without needing to know computer programming. Further,

the skills acquired through this process will complement the ability to write computer code and will add a valuable dimension for students who wish to pursue a career in digital design.

Digital Storytelling in Action

The King Island Digital Stories (KIDS) project (Masters 2017) was designed to develop children's digital literacies and teach them about digital design through creating digital stories about their sense of place. The project was conducted with 21 children in a Year 4/5 class over a 10-week term. An ethnographic approach was used where two researchers worked with children in the classroom as active participant-observers (Johnson et al. 2006) to scaffold children to represent their story ideas. The children were told that their stories could be about any aspect of living on King Island and they should be in their own voice (first person).

The project was slow to start, but a weekly sharing session helped the children to conceptualize and develop their stories. As the resources began to emerge, it was evident that the children were engaging effectively with the process of digital storytelling, learning about digital design, and developing their digital literacies. The children each produced a short digital story in iMovie about their life on King Island and used a combination of still images, transitions, narration, video, green screen footage, animation, and/or music to create their resource. These stories were published on a website and were publicly available on the Internet. The stories were varied widely, but collectively communicated a picture of life on the island through the children's eyes.

The research found that, as a result of the project, the children's digital literacies developed considerably to include aspects such as image manipulation and audio production and concepts such as copyright and cyber safety. Further, the activity facilitated an authentic project-based design experience for the children, and this was sustained for an extended time period. There was also evidence that the children had embraced the genre of digital storytelling for their own purposes and were keen to create more digital stories after the project had concluded.

Digital Storytelling to Teach About Digital Design

All citizens of the digital age need a strong understanding of how digital technologies work and how they can be used to enhance their own lives and those of others. Many of the children in schools today will be employed in contributing to the technologies of the future, and their motivation and interest will be formed from foundations that are built when they are young. It is essential that teachers do more than simply use digital technologies in the classroom. Teachers have a responsibility to develop knowledge, understanding, and skills so that their students can confidently design and create digital solutions.

Code is the language used to create computer applications, and it has an important role in developing technological futures. However, this is a language that is completely foreign to many generalist teachers in schools, and as such, they lack the confidence to teach children how to write and apply it. As a consequence, many teachers either avoid implementing code-based projects in their classrooms or conduct “safe” programming activities, such as using task cards, so they can avoid the open-ended problem-solving required with digital design. The insistence that computer coding is taught across all levels in order to enact the digital technologies curriculum may be actually be impeding the capacity of teachers to lead meaningful digital design projects.

The Australian curriculum specifies that students need to be provided with “authentic learning challenges that foster curiosity, confidence, persistence, innovation, creativity, respect and cooperation” (ACARA 2018) in order to help them become “innovative creators of digital solutions.” It is possible that digital storytelling can provide a platform for teachers do this with more confidence. While teachers still need to scaffold learners through the process of development and cycles of problem-solving, the genre of storytelling is likely to be more familiar and comfortable for them. This familiarity will help them with their own skill development and therefore enable them to successfully lead their students’ endeavors.

Conclusion

Digital storytelling is a lovely way for children to learn about digital design. While it doesn’t involve hard-core programming, it offers plenty of opportunity for children to engage with real-world design skills, and it will certainly foster the traits specified by ACARA (2018). Further, digital storytelling provides a nice alternative for teachers who might struggle with the prospect of teaching programming. This will ensure that the classroom will become an environment where all learners, the teacher and the children, will be able to succeed in their digital design adventures.

Cross-References

- [Digital Literacy, Creativity, and Autonomous Learning](#)
- [Digital Storytelling in Teaching and Research](#)

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Digital Teaching of Mathematics

► Mathematics Education and Technology

Digital Technologies

► Digital Technologies in Higher Education, Learning Challenges

Digital Technologies and Literacy Contexts for Young Indigenous Children

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Synonyms

Digital storytelling; Early years literacies; Indigenous literacies; iPads in the early years; Multiliteracies

Introduction

Acknowledgment of the ways in which becoming literate empowers children and adults to function at high levels in everyday life and participate in active social futures has been internationally recognized for a long time (New London Group 1996). With this in mind, it is apparent that young children enjoy using new (digital) technologies, yet many school-based learning contexts seem to be ambivalent about using them for literacy learning. For example, Flewitt et al. (2015) note that:

Children's immersion in digital communication occurs at a critical period in their lives when their emerging literacy skills (speaking, listening, reading and writing) and identities as effective and competent learners are being moulded by the conventions of the social and cultural worlds in which they live. (p. 291)

Accordingly, it becomes important to understand the ways in which learning ecologies can stimulate interest in becoming literate in our changing world, in contexts that incorporate the use of digital technologies.

The teaching of early literacy remains highly contested (Lynch and Redpath 2014). Internationally, reviews of the teaching of literacy/reading (e.g., in the United Kingdom, Layton and Miller 2004; the United States, Goodman 2011; Australia, NICHHD (National Reading Panel) 2000) have advocated centrally mandated standards-based curricula where “essential” knowledge and “basic” skills are stated and taught explicitly. The curriculum expectations are accompanied by an assessment and accountability testing regime that reinforce a traditional view of literacy based on encoding and decoding print texts (Lankshear and Knobel 2003). While there have been policy statements that endorse and promote the use of digital texts and experiences (e.g., DEECD 2006), the focus of early year's literacy curricula and classroom practices that are “print” based provides a stark contrast to our contemporary understandings of multiliteracies (Kalantzis and Cope 2012; Kress and Jewitt 2003; Lankshear and Knobel 2003) and the ways in which we know

young children can use new technologies (Marsh 2004; Plowman et al. 2010; Yelland 2007, 2017).

Thus, many classrooms still do not afford contexts and opportunities for young children in modern societies, to prepare for global social futures. Teachers receive contradictory messages about the value of new technologies for teaching and learning and often default to print literacy contexts in order to meet the standards required of them and the young children in their classes. In contrast, in out-of-school contexts, young children are excited by, and fluent with, digital texts and experiences (e.g., Marsh 2004; Rowan and Honan 2005). In this way, while definitions of literacy are changing, and the uses of digital technologies are increasing, the focus has remained on traditional literacy skills that “constrain and devalue student enactment and position literacy learning as a ‘struggle’ to encode and decode rather than a means of pleasurable self-expression” (Lynch and Redpath 2014, p. 150). Accordingly, heritage curricula are regarded as being inadequate to empower and prepare students for lives in the twenty-first century and are even at odds with their home experiences (Marsh 2004; Yelland 2007).

Becoming Literate in the Twenty-First Century

There would seem to be general agreement that being literate is a fundamental skill in order to be able to fully participate in society and forms the basis for lifelong learning (UNESCO 2016). However, what “counts” as being literate has changed over time. A broad definition of literacy (UNESCO 2004, p. 13) has wide acceptance and encapsulates skills, cultures, and contexts:

Literacy is the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials associated with varying contexts. Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society.

Becoming literate in the varied contexts of oral, written, printed, and digital media is essential to being able to function effectively in contemporary societies, and this process is enabled by using the “21st century skills” (Trilling and Fadel 2009) of creativity, critical thinking, collaboration, and communication. Research has challenged conventional print-based definitions of literacy, and a variety of studies have illustrated the ways in which digital technologies make an important contribution to early literacy competencies (Flewitt et al. 2015; McKee and Heydon 2015; Plowman et al. 2010; Yelland and Gilbert 2013, 2014).

Additionally, the foundational skills and concepts required to become literate and numerate are an integral part of being a new learner in the twenty-first century. We consider literacy and numeracy together here because it is almost impossible to separate them, and we believe they establish the foundation for all subsequent learning. This process begins at birth and occurs across both formal and informal contexts of learning. Fluency in literacy and numeracy *enables* the 21st century skills and supports *growing a generation of new learners* who are able to fully participate in society. It is essential that a range of pedagogies (teaching strategies) be used so that children can both acquire the foundational skills and apply them appropriately and creatively in relevant contexts that constitute their lifeworlds.

Multimodal Learning, iPads, and Learning in the Early Years

It is contended that one of the significant differences about learning in the twenty-first century is that it is *multimodal* (Jewitt 2003; Kress and Jewitt 2003; Yelland 2007, 2015). Young children experience learning in a wide variety of contexts and learn with different resources that are found both in their “real” worlds and via new technologies. *New learning* (Kalantzis and Cope 2012) requires teaching strategies and opportunities for learning to meet the needs of communities of learners who are experiencing changing social

futures. New learners are responsive to change and dynamic in their thinking so that they are able to adjust to changing times effectively. They are enacted from a sound knowledge base of *foundational* skills that enable ideas to be generated and tested. They are encouraged by learning experiences characterized by engagement with new ideas, inquiry, exploration, curiosity, and a passion for learning. They exist in communities of learners who have a strong sense of social justice and empathy so that being a good citizen is an integral part of the moral imperative of their education.

In planning for these imperatives, it is essential, in the twenty-first century, that all children have access to new technologies and that they are able to use them, when appropriate, to learn. New technologies incorporate the range of devices (hardware) that are available in the marketplace. They are ubiquitous and constantly changing and include computers, tablets, smartphones, and a myriad of other mobile devices. For the past 5 years, there has been an increasing surge of interest in the iPad for learning (e.g., Flewitt et al. 2015; Lynch and Redpath 2014; Rowe and Miller 2016). Their touch pad technology, and mobility, meant that they could be used easily and widely. Many research projects have explored the viability of the new technology and presented exemplary studies based on empirical observation data (e.g., Agostino et al. 2016; Lynch and Redpath 2014; Rowe and Miller 2016; Yelland and Gilbert 2014, 2016). The research that has literacy as a focus (e.g., Flewitt et al. 2015) has generally shown that, with pedagogical support, teachers are keen to incorporate tablet technologies (iPads) into their early literacy experiences. Additionally, using iPads has provided increased and quality learning experiences that enable collaborations, communication, and independent learning. For example, McKee and Heydon (2015) conducted a fascinating exploratory study with kindergarten children and senior citizens, investigating the opportunities for print literacy to function in multimodal assemblages. Their findings provide evidence of deep learning via engagement with ideas and people and opportunities to refine their print literacy capabilities in

the context of multimodal ensembles. Further, Rowe and Miller (2016) explored the potential of iPads for bilingual preschool children to create eBooks over a period of 2 years. Their work illustrated the potential for multimodal representations to enhance literacy in both languages that were not possible without the technology. Agostino et al. (2016) worked with struggling readers and a particular letter-focused application (app) called *LetterWorks*. This study illustrated that there is a need to incorporate the use of iPads, or other technologies, into literacy activities as a whole and not view them as isolated learning opportunities. Further, they stressed the need for teachers' philosophical stances to be aligned with using new technologies for learning.

From the studies available, it becomes apparent that the apps available can be considered in many ways or categories, but at a practical level, to consider them on a continuum from entry level to advanced is useful. *Entry-level* apps can be basically designed for entertainment, but they can also provide contexts for being introduced to the foundational skills of literacy and numeracy (e.g., introducing letters and numerals and simple words) in a stimulating way. *Advanced* applications stimulate creativity, critical thinking, collaborations, and the sharing of ideas and are only possible in environments that encourage diversity and personalized learning. The difference has been characterized in terms of being a *consumer* or *creator* with the support of new technologies (Yelland 2007). The latter role resonates with new learning, providing experiences required to excel in contemporary times. But, in fact, children are unable to engage with the higher levels of learning required in the advanced apps, unless they are fluent in the fundamental skills. As such, learners should be supported to participate in a range of activities from simple to more complex. Hence, the type of applications becomes of major importance.

Young Indigenous Learners

The issue of young Indigenous children experiencing problems attaining the benchmark levels

of attainment in literacy and numeracy has been identified as being a problem for over a decade (Frigo et al. 2004). This is not unique to Australia, as Hare (2011) has noted. The same trends are evident both in Canada and New Zealand. Hare (2011) also stated that in order to attempt to address the issue, the “challenge for educators who work with Indigenous children. . . is to create a space for Indigenous knowledge. . .” (p. 408). This needs to begin in the early years since research has indicated that it is overwhelmingly evident that the early literacy ability is a strong indicator of later success in school (e.g., Roberts et al. 2005; Senechal et al. 2006). The “funds of knowledge” framework (Moll et al. 1992) informs us about the importance of valuing and incorporating family knowledge as part of any early literacy program. While it is widely recognized that we live in a multicultural society (and in Australia, where this topic will be considered in depth, this is increasingly important), it is also evident that there is minimal research about how we might enact this in schools with Indigenous students to address the significant difference in achievement. Hare (2011, p. 391) has in fact suggested “Developing an awareness and appreciation for Indigenous approaches to living and learning will provide the basis for improving the home-school connections that being with early childhood for Indigenous families.”

Indigenous ways of knowing and being have their origins in an oral tradition of storytelling that has continued into modern communities (Burnett 2015). Additionally, we know that maintaining cultural relevance and providing local experiences to locate knowledge building are a fundamental aspect of learning for young Indigenous children (Brady et al. 2003; Nakata 2003). Nakata (2003, p. 12) advocates a “ground-up” approach and contends that this has to take place with the realization that the “forms of literacies that are required to understand the world are constantly changing.”

Burnett (2015, p. 44) highlighted that at the core of Indigenous knowledge is its “imaginative and pictorial character.” He advocated creating contexts for learning where oral storytelling is encouraged so that children can become aware

of the impact of spoken language. Nakata (2010) extends this idea by recognizing that this tradition can incorporate “writing” in order for the children to build a repertoire of literacy practices so that they are able to function more effectively in contemporary society. Hare (2011) maintained that this was possible since Indigenous ways of knowing resonate with emergent theories of multi-literacies and multimodality. She advocated that pedagogical approaches that were culturally specific were needed in order to support emergent literacy learning for Indigenous children. These included sharing stories based on personal experiences that can arise out of increased awareness and interactions with families in communities. These enhanced collaborations can then be documented with the use of digital technologies (Yelland 2007; Yelland and Gilbert 2014) in multimodal formats. The benefits are enormous since, as Hare (2015) noted, when the use of Indigenous narratives is incorporated into learning experiences, literacy skills (e.g., story knowledge) result in increasing vocabulary and comprehension, which are essential foundational skills for early literacy.

Digital Empowerment: Emerging Digital Literacies

The remainder of this section discusses the potential of iPad technology to enhance emerging literacy practices for preschool Indigenous children in Australia through a case study. Indigenous children have been found to be performing less well than their nonindigenous counterparts in national literacy tests at primary and secondary school levels. This study involved working with teachers and children in four Indigenous preschools in order to investigate how to support their literacy and numeracy learning using iPads. The design included a plan to build on Indigenous oral literacy traditions that would enable the children to acquire the foundational skills to support and empower them to become fluent in extending their abilities to read and write in varied modalities. This rested on the belief that all children need foundational skills in literacy and that the early

years were vital focal points for learning. The foundational literacy skills included being able to recognize letters, sounds, some everyday words, knowing and using numbers, recognizing shapes and objects, and being able to articulate events and everyday practices that occur in conversations. In this project opportunities for the children to consolidate their foundational skills with iPad apps were planned linked to the preschoolers' everyday experiences and their specific cultural context. These experiences formed the basis of creating multimodal texts so that the children could read and continue to build their vocabulary as well as provide contexts for engaging with literacy, based in their own lifeworlds.

These experiences then formed the basis to build on Indigenous children's funds of knowledge (Moll et al. 1992), such as their oral literacy tradition, to create contexts for them to become literate as a fundamental right to living in the twenty-first century. It has become evident that in order to be "ready" for school and to participate in life after school, the foundational skills of literacy (and numeracy) are essential in order to access services and to contribute to communities in a variety of ways. Indeed, in the early years of school, being able to communicate ideas and represent your understandings effectively involves using these foundational skills on a daily basis. Such emergent skills can be encouraged and supported in quality early learning environments.

In Australia, like many countries globally, performance in literacy (and numeracy) is measured by national testing. In Australia, it is called the National Assessment Program Literacy and Numeracy (NAPLAN). NAPLAN was designed in order to "test the sorts of skills that the government believe are essential for every child to progress through school and life" (ACARA 2013, p. 67). There is an explicit recognition by the ACARA that being fluent in literacy and numeracy is foundational to later success in life and that the items in NAPLAN reflect the attainment of those skills. The most recent data (ACARA 2015) about test performances, which are conducted in Years 3 (8–9 years), 5 (10–11 years), 7 (12–13 years), and 9 (14–15 years), indicated that 18% of Indigenous students failed to reach the

minimum standard for reading and writing (6% for nonindigenous students). Sixty-one percent of Indigenous students were below the benchmark for spelling, grammar, and punctuation, while 78.7% were above the minimum standard for literacy in Year 3 (95.6% for nonindigenous).

In 2008, the Council of Australian Governments (COAG – Closing the Gap on Indigenous Disadvantage. https://www.coag.gov.au/closing_the_gap_in_indigenous_disadvantage) agreed to six targets that sought to address the disadvantages faced by Indigenous Australians. These goals pertained to life expectancy, child mortality, education, and employment. Two of the goals directly relate to research of a project reported here. They were to:

- Ensure access to early childhood education for all Indigenous 4-year-olds
- Halve the gap in reading, writing, and numeracy achievements for all school-aged Indigenous children by 2018

The project, known as *Closing the Gap*, had broad goals to support Indigenous health, welfare, and education and planned to encourage early childhood development as well as significant investments in schooling. The National Partnership Agreement on Indigenous Early Childhood Development was designed to provide early learning and support for Indigenous families and stated targets for improved health for both mothers and their children. One of its major aims was to improve Indigenous families' use of early childhood development services to optimize the development of the children, and an overarching goal was that Indigenous children should acquire the basic skills for life and learning. Another goal was to "prepare children for school" (p. 30) with growth in literacy and numeracy attainment being viewed as an essential part of this process. One of the findings from the final report (Final report on Indigenous early childhood development. <https://www.coag.gov.au/sites/default/files/Report%20-%20Evaluation%20of%20the%20National%20Partnership%20Agreement%20on%20Indigenous%20Early%20Childhood%20Development.pdf>) indicated that there was anecdotal evidence

that early learning activities in the child and family centers were leading to children being better prepared for school. Implicit in the plans and the actions taken as part of the project was a recognition that investment in the early years pays “significant dividends later in life” and that the investments “are making a positive difference” to the lives of Aboriginal and Torres Strait Islander children, families, and communities. There was a recognition that evidence-based practice was needed to support the sharing of exemplary educational practices since these had the potential to transform the lives of Indigenous children as they progressed through schooling systems to achieve more favorable outcomes.

Indigenous Literacies

This project was based on the contention that in order to encourage and facilitate new learning in the twenty-first century, Indigenous learners need access to new technologies and to be provided with opportunities to master the fundamental skills of literacy and numeracy and opportunities to apply them in culturally relevant ways so that their experiences are meaningful and learning outcomes improved. This will then provide the context for decision-making about life choices, such as employment and participation in society. Thus, there is an imperative to *grow a generation of new learners*, and this begins in the early childhood years.

The study was grounded in sociocultural theories of learning (Vygotsky 1978) in which children learn in a social context before internalizing any new information. This approach resonates with taking an Indigenous perspective to knowledge building that is culturally based in the oral tradition of storytelling as well as linking to the notion of social futures inherent to pedagogies of multi-literacies (New London Group 1996) and multimodality (Kress and Jewitt 2003).

The Context of the Study

The study was designed to explore and document pedagogical contexts for using tablet technologies

(iPads) in early learning scenarios (4-year-old kindergarten groups). Four centers participated in the project. They were part of the Multifunctional Aboriginal Children's Services (MACS) system, located in the capital city of the state and in three regional centers.

The study was designed in order to consider the potential for *new learning* (Kalantzis and Cope 2012) with *new technologies* and support teachers to use tablets to transform their pedagogies and practices in early childhood Indigenous education. There was a stated need for evidence-based practice to support culturally appropriate ways of becoming literate and numerate. The aim of this project was to document and share what might work, since we believed these had the potential to transform the lives of Indigenous children in other locations.

Previous research (e.g., Yelland and Gilbert 2013, 2014, 2016) had shown the variety of ways in which tablet technologies could benefit learning in preschools. This project sought to extend this work with Indigenous educators and children to encourage new learning that was culturally relevant and would enable the children to acquire fundamental skills in literacy and numeracy that they could apply in diverse contexts. The researchers participated by observing and interacting with the children, caregivers, and teachers, in a participant observation methodology. Participant observation can be defined as a method in which “the researcher is taking part, to some degree, in the activities of the people being observed” (Deacon et al. 1999, p. 251). The aim of participant observation is to gain access to everyday practices, which are difficult to describe or reproduce in group discussion or interview (Mikos cited in Struppert et al. 2010). Through participation in the context, the researcher can achieve a better understanding of the practice, roles, and cultural patterns of the participants (Mikos cited in Struppert et al. 2010). Visits were made to the MACS on a regular basis. For the MACS located in the city, this was 1 day a week for 6 weeks in terms 2 and 3. For the rural centers, the visits occurred on two occasions for 2 days in length, during the same terms.

There were three sources of data in the project. First, daily reflective notes reflected the events of the day recalled as a narrative. These included descriptions of the children using the apps as well as conversations with the children as they embarked on various play-based experiences. Second, the educators in the three centers shared their planning documents and observations by making them available to the research team as well as in conversations with them during the visits. All of the educators were interviewed in their centers, prior to the start of the participant observation period. This was in a semi-structured interview schedule which included questions about how they viewed the role of technologies in the lives of young children, the advantages and any disadvantages of using them, the types of apps they thought were the most useful for their program and why, and what were the differences in learning that they perceived were happening from using the iPads. In analyzing the data, themes were derived to describe the children's interactions in the learning environments in the ethnographies and then linked with the data derived from the interviews with the educators and with their planning documentation to explore the ways in which using the iPads was connected to their beliefs as well as their design of learning experiences.

A total of 10 educators and 63 Indigenous children participated in the study. The average age of the children was 4 years and 3 months with a range from 3 years and 7 months to 5 years and 5 months. The educators were experienced, with each one having taught preschool children for over 5 years. Seven of the educators were Indigenous and three nonindigenous.

The Apps

Apps were chosen in consultation with the educators. They were trialled prior to the commencement of the project to determine their usefulness prior to purchase. There were many more entry-level apps than open-ended creative ones. The apps were introduced to the children as they showed interest in using them. The advanced

apps were introduced by the researchers, and the children were invited to participate and play with them if they wanted to. There was a planned visit to the local cultural center, and an Indigenous Children's Day occurred while the research was in progress. Both of these events provided a context for creating an electronic book while the study was in progress.

The entry-level apps enabled young children to start recognizing each letter and lead to reading words and creating their own stories. There are a great many of them available on the market. For example, in *Alpha Tots*, each letter of the alphabet is introduced individually by name, and then a word beginning with that letter is accompanied by a graphic so that the child can see how the letter is used in context. This is done for both objects (e.g., book, car, house) and actions (e.g., mix, fix). In *iWrite*, children are able to use their fingers to trace over the letter or numeral and feel how it is shaped in a very tactile experience.

Entry-level apps were used to support the acquisition of fundamental skills in literacy and numeracy. In literacy, this meant recognizing letters and the corresponding sounds and sound blends and building a strong vocabulary of everyday names and activity words. For numeracy, it included:

- The ability to recognize and use early mathematical *language* such as positional and relational terms (e.g., up, down, over, under, in, out), using, for example, *Bugs and Buttons* and *Bugs and Numbers*
- The *names* of colors and shapes, using, for example, *PB Shapes and Colors*
- *Using* the basic processes of describing attributes, matching, sorting, classifying, and making and using patterns, using, for example, *Bugs and Buttons*
- *Recognizing and using* numerals to create groups of specific numbers of items and combining or reducing them as an early introduction to addition and subtraction in context, using, for example, *iWrite numbers and letters*, *Alpha Tots*, and *Monkey Preschool Lunchbox*

Many early reading books and resource materials do not contain representations of Indigenous

children. In this project, advanced apps (*Book Creator*) were used to create eBooks that included the children themselves in the storyline. Aspects of the children's daily lives were included so that they could apply their learning and be involved directly in making and interpreting the eBooks. The study included learning contexts in which the children were challenged to explain their experiences using (oral and written) language. The camera in the iPad meant that everyday play activities could be photographed, or videoed, and saved for later conversations about aspects of the play scenarios. For example, if the children built a construction with blocks, subsequent discussions about the relative sizes of the blocks, their position in the structure, and how many blocks were used could occur. Similar discussions could be had about a painting or a collage or in relation to any of the indoor or outdoor activities planned by educators.

The Educators

The data from the semi-structured interviews revealed that the educators ranged in their own levels of confidence with new technologies and their feelings about using them. However, they all indicated that they were "excited" and ready to "embrace" the iPads and ready to learn new ideas that they could try out with the children in their kindergarten, which were preschool centers with children (aged 4 years) in the pre-compulsory years of education.

They all indicated that the *Early Years Learning Framework* (EYLF) (Department of Education, Employment and Workplace Relations 2009) was an important policy imperative that guided their work. The EYLF provided the context for early learning and the reporting framework for all early childhood educators in Australia. It was designed to support learning contexts in which all young Australians become:

- Successful learners
- Confident and creative individuals
- Active and informed citizens

The framework characterized children's lives in terms of them *belonging*, *being*, and *becoming*, and it had five learning outcomes that were inter-related and supported deep learning (defined below) via careful planning of experiences. They provided the contexts for children to:

- Have a strong sense of identity
- Be connected with and contribute to their world
- Have a strong sense of well-being
- Be confident and involved learners
- Be effective communicators

Fullan and Langworthy (2014) contextualize deep learning by describing it as being based in new pedagogies focused around creating learning partnerships between, and among, teachers and students. The dynamics of the new relationships mean that the students are more engaged and have more autonomy over designing their learning experiences. Their learning scenarios are based in authentic experiences enabled by new technologies and usually designed by the students themselves as investigations. In this way, deep learning opportunities are created.

The EYLF suggests that information and communication technologies (ICT) can be beneficial for planning learning opportunities in the early years. There is recognition that ICT can support collaborative explorations and investigations and that they constitute a medium for expressing and communicating ideas. However, in reporting for accreditation purposes, examples need to be provided in the form of observations of children engaging in learning.

In the conversation with the educators, it was evident that they felt a primary goal for kindergarten which was to have the children "school ready" by the end of the year. They indicated that this, in part, included that at the end of the kindergarten year, the children would be able to recognize the names and sounds of letters of the alphabet and numbers up to 10. Yet they recognized the value of social aspects of learning, such as collaborating with others and being able to be engaged in an activity for a sustained period of time. Each one of them thought there was an imperative to have

technology, such as iPads, in their kindergarten room. They made statements to indicate that they felt that using technology was essential for living and learning in the twenty-first century, particularly for Koori (Indigenous) children as many did not have them in their homes. So, the educators thought that coming to kindergarten and having both structured and unstructured learning experiences with the iPads were important for the children's early learning. They viewed the advantages of using iPads as being related to engagement with learning, improving fine motor skills, having opportunities for new and challenging experiences, preparing children for the "real" world, and enabling them to find out new information. They viewed the disadvantages in terms of being able to manage the time around the use of the iPads and of sharing them between the children in the groups when so many wanted to use them. This was also related to concerns that the children would become too reliant on them in their play and that they would want to use the iPads exclusively and not play with traditional play materials. They also expressed a concern about safety issues online.

Emerging Literacy Skills

Observations revealed that the entry-level apps afforded opportunities for the children to acquire the foundational skills of literacy and numeracy. The experiences with the entry-level apps represented a focused time on particular skills and concepts that the educators could build on in their conversations with the children while they were playing with them, as well as in other learning activities. They could also help the children to make connections about the concept with the different activities that were provided as part of the planned program in the kindergarten.

For example, with the app *Alpha Tots*, it was observed that the children made connections between the various letters of the alphabet and the letters that make up their own names as well as familiar items (table, chair, and carpet) around them (Fig. 1). The audio features of these apps also helped those children who experienced

problems with the pronunciation of words. The apps encouraged children to recognize letters and words and to say them out aloud. For example, when the letter "c" was introduced, it was accompanied with the name of the letter and the hard "c" sound. The action of cutting was introduced with the cutting of the strings on some balloons. In response, one child, Brian, immediately said "balloons" start with a "b".

In interactions with the children, it was noted that once the letters were recognized, they could be combined to make words, so that in an app like *Monkey Preschool Lunchbox*, various words could be read aloud. The educators were encouraged to talk with the children both individually and in small groups and ask them questions such as:

- What letter is this? What sound(s) does it make? (Strawberry starts with "S.")
- Can we think of a word that starts with this letter? What about another word? (Sally starts with an "S" and Sand starts with "S.")
- Can we think of a word that has this letter at the end? (Cars end with an "s.")
- This fruit is yellow. What other things can you see that are yellow?

These conversations became an integral part of the learning process.

By using apps such as *Alpha Tots* and *Monkey Preschool Lunchbox* with their visual, audio, and



Digital Technologies and Literacy Contexts for Young Indigenous Children, Fig. 1 Alpha Tots

linguistic learning experiences, conversations about letters, sounds, and words with the educators proved to be very worthwhile. With apps such as *iWrite*, the children could trace over letters and numerals, and the experiences became tactile. This enabled them to become familiar with the structure of letters and numerals and how they felt. In doing these activities, the children were guided by the app in a structured way, in terms of the direction of each stroke, and were then able to transfer this experience to paper and pencil representations of the letters and numerals. At the same time, the children were extending their personal vocabulary of words and numbers, which they could then apply to other learning activities.

Playing with apps like these, and talking with their educators, enabled the children to experience early literacy concepts in dynamic interactive contexts that built on and extended their “real-world” play experiences. Taken together, these multi-modal learning opportunities prepared the children to experience reading with both electronic and traditional reading books.

During this phase of the research, eBook stories were read with the children such as *Teddy's Day* and *Peppa Pig at the Fair* in order to build on the foundational skills. These eBooks extended traditional reading experiences in a variety of ways. First, the eBooks had “read along” modes. A child could choose just to listen to the story in tandem with the pictures. Second, the story could be retold using their own words.

Each book contained a series of activities on each page that extended the scope of the book. For example, on one page in *Teddy's Day*, children could create a drawing, which then went on to the wall of the living room in which the character is playing with her Teddy on that particular page (Fig. 2). Alternatively, they could make a jigsaw with the characters as they were playing. With the *Peppa Pig* book, they could choose to modify the text by recording their own words for any page. The pages of the eBooks were full of items and actions that acted as a catalyst for language and conversations about a wide variety of things that children found interesting, which might be about dancing (there were dancing mice in *Teddy's Day*) or eating fairy floss at a special event (*Peppa Pig*).

Having opportunities to use the foundational skills, concepts, and language was not just experienced with iPad apps. Using the tablets formed part of the daily program and was linked with other play materials located both inside and outside the classrooms. In the study, it was found that the experiences with the apps on the iPad acted as a catalyst for more focused conversations when the children were playing in other areas of the center. On one occasion, after playing with *PB Shapes*, Marlowe (pseudonym) was playing in the outside area, and he called to Lara (educator pseudonym) and said “Look Lara, there are shapes out here like in the game. I can see a square and a circle and a rectangle over there!”

Digital Technologies and Literacy Contexts for Young Indigenous Children, Fig. 2 eBook: Teddy's day drawing on the wall



Scenarios such as this happened both spontaneously and with scaffolding from the educators. All the educators were familiar with basic mathematical language, concepts, and beginning skills from a professional learning experience around *Early Mathematical Explorations* (Yelland and Gilbert 2014) that happened in the year prior to this project. This project took an integrated and practical approach to language and conceptual learning from birth and provided educators with strategies to support early learning for literacy and numeracy.

It is recognized that once children have acquired foundational skills, they are able to communicate and make meaning in more effective and sophisticated ways. In this project, the children were to *apply* their knowledge and skills in new and diverse ways and were able to use the iPads to do this as well as in other play-based activities.

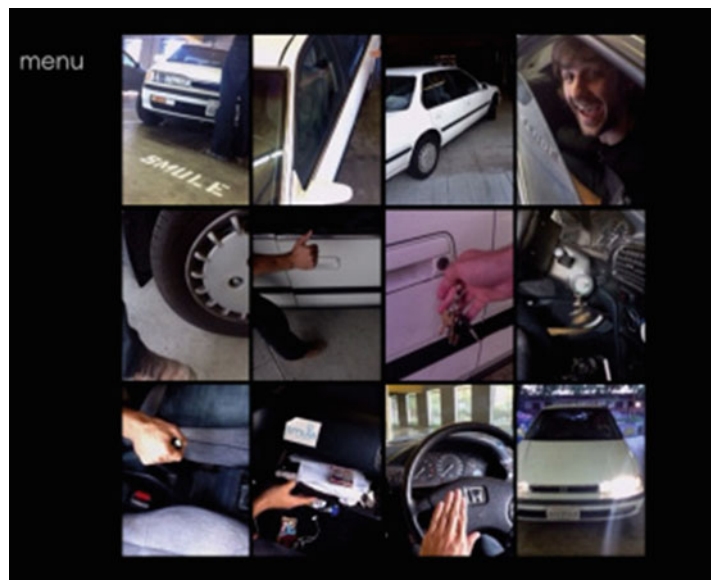
This Is Me! An Introduction to MadPad

When children are able to engage in conversation with others, they can embark on different levels of meaning-making in which they can describe and create new narratives. *MadPad* is an app that enables a montage of 12 pictures and sounds to be created and replayed (Fig. 3). One of the things

that was found useful when introducing a new creative app such as *MadPad* to young children was to show them an example. They could then use this to help produce their own version or innovate on it because they could see some relevance of it to their own experiences and interests. In this instance, *MadPad* enables users to view and play with other users' *MadPad* creations on the Internet and share on *YouTube*. In one, a series of 12 photographs and sounds of a car were arranged in a 4×3 matrix, and in others, there were various scenes and sounds from daily lives as well as others using a range of musical instruments. The idea is that the clips are short (10 seconds) and "snappy" and can be played individually or collectively. It is the range of sequencing the items and innovating on the sounds that makes it fun and lifts its creative potential so that each time it is a different experience.

For the young children in the centers, the *MadPad* montages provided the context for a short burst of conversation or sound creation that could then be linked with others to form a whole matrix of sounds. These then acted as a catalyst for exploring the sounds or ideas encapsulated in the matrix of videos. When working with preschoolers, it was found that several "takes" with each child were needed before they could use the

**Digital Technologies and
Literacy Contexts for
Young Indigenous
Children, Fig. 3** MadPad



10-second recording. At the most simple level, MadPad montages in which the children introduced themselves and said what they liked best were developed. For example, “My name is Mira and I like cows!” Other completed montages included a collection of playground sounds, favorite spots in the garden, and a statement about favorite animals. All of the MadPad montages were played with repeatedly by the children and led to a rich source of conversations.

Creating Scripts with Play School and Sock Puppets

Two other creative apps were useful to encourage talk and build vocabularies. *Play School Art Maker* lets children create various scenarios with their favorite characters from the popular television show. The children can choose a setting (e.g., a farm, the beach, underwater, bedroom, or the moon), place the characters and appropriate items in the scene, and then record a 1-minute video in which they can add their storyline with their voice. The videos can be compiled and made into an eBook or simply be saved in the app for later viewing. The scenes created provide very useful catalysts for talking about the various forms of mathematical language. They can stimulate conversations around positional and relational terms and incorporate activities such as counting and finding patterns in the scenes that have been created. The children loved to playback their creations and share them with their friends. In the process, they talked about the various characters and items in each scene as if they were friends. Each video constituted a multimodal language experience that was created by the children themselves.

In *Sock Puppets*, a background and characters can again be chosen and incorporated into play-based scenarios. They range from endearing “Sesame Street”-type characters to ghosts and aliens. Backgrounds and props can be selected before a play is created. When the children began playing with *Sock Puppets*, they often just uttered “gibberish” and made sounds, but as they became more familiar with the genre, they created short

interactions in which they played both parts of the puppets they were creating. For example, Susi chose two Muppet-like puppets – a (pink) girl with yellow hair and a pink “animal” puppet. She placed them in a “country” scene background and then created her script spontaneously:

S: (with puppet 1 (P1) the girl) We are in the bush Spotty

S: (with animal puppet (P2) highlighted) I like it here. It's sunny

S: (P1) Run after the ball Spotty

S: (P2) I can catch it!

The children seemed to enjoy these activities and carefully thought about the words that they might use when they were recording their short play sequences. They encouraged the children's talk and, after the initial play sessions where they first found it difficult to figure out which puppet they had to speak for, became adept at creating short scenes like the one above.

Advanced Apps: Making eBooks with Book Creator

By far the most advanced and exceptional use of the iPad was in the creation of eBooks with an app called *Book Creator*. These eBooks could also be saved as *iBooks* in a different app. Kindergarten-aged children (4 years old) are in the process of acquiring literacy skills that enable them to explore the world and share their ideas with others. They need to practice their skills in a rich variety of contexts. This may include playing at shopping and using the appropriate terminology; using items and engaging in conversations; talking about constructions while playing with blocks; and creating eBooks on the iPad.

The availability of children's books that include Indigenous children as characters is limited. It is possible to explain to educators how to build their own books, and after a few examples, they are able to create their own. The books made in this project included the children in the centers, and their everyday experiences were the source for the stories in each of the texts. These included:

- An Indigenous children's celebration day: on this day the center arranged for a range of activities including both modern and traditional Aboriginal dancing groups.
- A visit to the local Indigenous cultural center (see Fig. 4).
- Making a book about aliens, which seems to be a constant source of curiosity to children from every culture.
- Exploring the garden created at the center.
- Playing in the playground (see Fig. 5).
- Finding out more information about our group of friends.

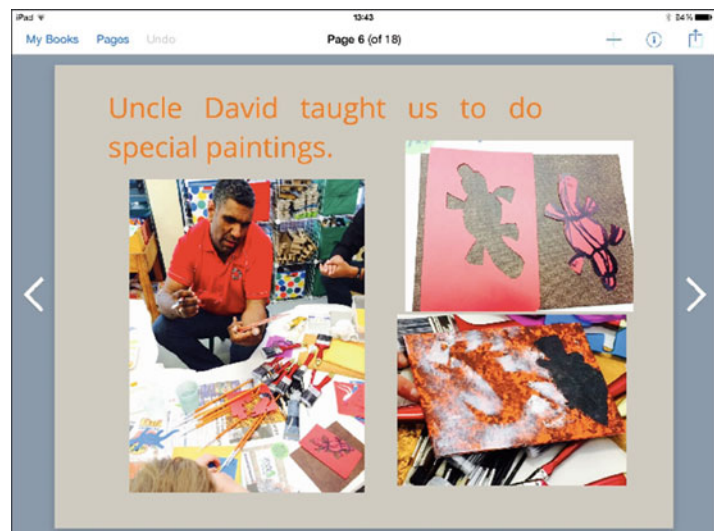
The eBooks were multimodal. They included text, drawings, photographs, and videos. The text was both written as well as being spoken by the children. When the books were finished, the children could share them between the two iPads in each center via *AirDrop*, and then they could be read whenever any child chose to do so. This was quite frequent, as the books seemed to take preference over traditional books. The eBooks provided a context to practice reading and for listening to stories. The narratives had direct and personal relevance to the young children's lives. The children wanted to sit and read the books that they had made themselves. This, in turn, had the effect of increasing their vocabulary and improving their reading capacity.

The use of the iPads to make eBooks documented the activities that the children participated in. They illustrated examples of using literacy and numeracy in meaningful ways. For example, at a local cultural center during one session, the eBook became a dynamic and permanent record of the day's events that could be revisited at any point in time when individual or groups of children wished to recall them. In this particular example, the visit to the cultural center included hands-on experiences with traditional artifacts as well as listening to Uncle playing the didgeridoo and the children guessing which animals he was mimicking on the "didge." Uncle could not be present back in the center, so the book became a permanent recollection of his playing and the children loved to recall this in their later reading of the book.

Some centers also decided to print the books as well as have them in the electronic format. This provided the context for another dimension of multimodal representations of the books and conversations around why the video could not work in the printed version – a feature that was important for many of the children in the various groups. A benefit of printing the eBooks was that they were able to use QR (quick response) codes. QR codes were created using an app called *QR Code Generator*. For example, an eBook was made about a scooter race held at a kindergarten one

Digital Technologies and Literacy Contexts for Young Indigenous Children,

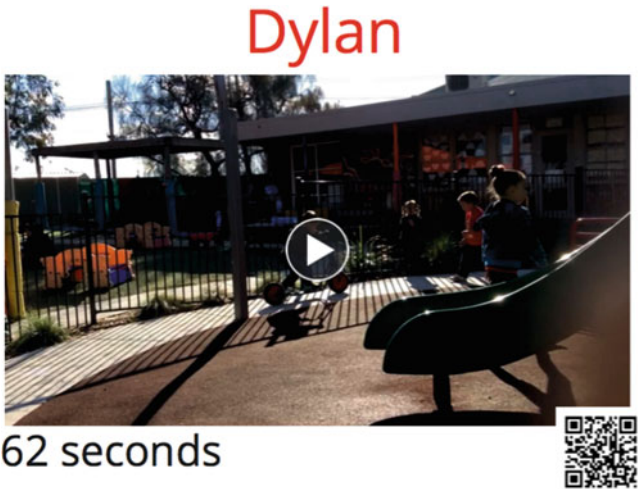
Fig. 4 Bangerang painting



Digital Technologies and Literacy Contexts for Young Indigenous Children, Fig. 5 In the playground



Digital Technologies and Literacy Contexts for Young Indigenous Children, Fig. 6 QR codes: Scooter race



morning. The eBook contained videos of each child racing around a track in the playground on the scooter. These videos showed how long each child took to complete a circuit. The aim was to find out who was the faster on the scooter in the group. Each of the videos was then uploaded to a private *YouTube* account, using the *YouTube* app on the iPad, and assigned a URL. The URLs were uploaded individually into the *QR Code Generator* app, and a unique QR code was automatically created for each video. The unique QR codes were printed and pasted onto each respective page of the hard copy. The children could then use their iPads to scan each code to view their video.

In another example of using QR codes, a poster of the children’s favorite things was created. This included a photograph of each child in the group with a QR code placed next to the image. When scanned, the QR code linked directly to the video on *YouTube* of each child speaking about what they liked doing best (Fig. 6).

Conclusions

This entry has provided empirical examples of the ways in which iPad use, with a range of exemplary apps, has the potential to enhance, and extend,

new learning opportunities for Indigenous children as young as 4 years of age. In doing so, it provides contexts for them to become literate as these activities are embedded in play-based early childhood programs. The observational data have shown that this can be achieved in four specific ways. Firstly, they can support the acquisition of early foundational skills in literacy (and numeracy). There are a myriad of apps that claim to teach “basic” concepts. A small number can be used in explicit teaching moments while children are engaged in both outdoor and indoor play activities. The use of these “entry” apps in the case study’s playful context introduced, encouraged, and reinforced the application of these fundamental ideas and connected them to other learning activities in the centers. Secondly, it was not just being exposed to the apps that made them valuable learning resources. Teachers used specific pedagogical strategies to scaffold the children’s learning. They asked questions of the children while they were playing and encouraged them to articulate their responses orally. They modeled the use of the words and sentences in various activities and were able to encourage the use of skills and particular concepts that were complex and could stimulate multimodal thinking in a range of experiences. Thirdly, the iPads provided a medium in which the children’s everyday activities and participation in special events could be recorded and revisited. For example, in the project the *Book Creator* app was used to create eBooks that were constantly revisited by the children to recall what they had been doing at the center at that particular point in time. Finally, all the activities provided contexts for using language and communicating with other children and with adults. They became important focal points of conversation and constituted opportunities to use language in a variety of modalities. It was found that engaging in the iPad activities stimulated conversations between the children and that the educators were also able to engage the young children in interesting and sustained talking to build their early vocabulary and skills in reciprocal talking.

The data from the case study adds to the corpus of research literature discussed at the beginning of

this article that consider the ways in which digital technologies impact on the emergent literacy skills of young children. Rethinking twenty-first-century literacy to go beyond the print literacy imperatives to incorporate digital literacy opportunities is a major concern for research and practice. Recent studies (e.g., Flewitt et al. 2015; Lynch and Redpath 2014; McKee and Heydon 2015) have supported claims arising from practices that seek to do this, providing empirical examples of the ways in which this might be achieved.

Cross-References

- [E-Books Among Students, Advancements in Higher Education](#)

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Digital Technologies in Higher Education, Learning Challenges

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Synonyms

Active learning; Connectivism; Digital technologies; Higher education; Interdependency

Introduction

This entry explores the use of digital technologies in higher education. There is now widespread recognition that in the twenty-first century digital technologies, particularly portable hand-held devices capable of Internet connection, present opportunities and challenges to the way in which student learning is organized in schools, colleges, and institutions of higher education. Traxler (2010) suggests such devices are pervasive and ubiquitous, conspicuous and unobtrusive, noteworthy and taken-for-granted with everyone typically owning one, using one and often having more than one. Consequently, it has been argued that the availability of such devices, controlled mainly by the student and not the teacher, has the potential to change the traditional dynamics and pedagogical patterns of the learning environment (Burden et al. 2012). Education institutions, however, typically remain organized around spatial and temporal considerations such as buildings, timetables, calendars, and internal structures with student learning environments still bearing a worrying correspondence to those used in the previous two centuries.

The principal concern to arise is a need to reconfigure the role of the teacher and their relationship with the student, with the balance of arguments seen in relevant literature indicating a

need to provide the learner with greater control in a digitally enhanced environment. Traditional teacher-led environments, it is concluded, should move from direction and control to facilitation and guidance of learners, a process requiring new skills and knowledge on behalf of staff charged with leading student learning. This has been described as the transition of teacher from “sage on the stage, to guide on the side” (King 1993, p. 30).

Digital Technologies and Learning in Higher Education

The term “digital technologies” in this study refers primarily to multifunctional equipment or devices with Internet connectivity and particularly to devices that are hand-held and portable, a definition which generally means smart-phones and tablet computers. In exploring the opportunities offered through the combination of more traditional Internet access (fixed location) and personal Internet access (mobile), several trends have been identified which institutions of higher education need to explore, evaluate, and possibly adopt as they move forward in a new era. The principal focus of this entry is to explore how student learning could be enhanced through use of appropriate digital technologies.

With portable digital devices now being a core feature of the twenty-first century, this presents the possibility for a fundamental change to education, shifting from passive acquisition of someone else’s ideas to active learning experiences that empower people to inquire, critique, create, collaborate, problem solve, and create understanding (Dede and Barb 2009). With new technologies, information is continually being developed, distributed, and acquired and has become a paradigm that cannot be ignored within educational organizations. Selwyn (2007, p. 91) makes the case that these digital technologies could allow institutions of higher education to reinvent themselves, requiring institutions to make a shift “from the representational capabilities of ICTs (i.e., their ability to represent commoditized informational delivery modes of higher education) to their

more expansionist and relational potentials””. In examining these changes, the American Society for Training and Development (2009) not only reflected the way in which the “millennials” (those born between 1977 and 1997) approach learning but also identified the need to incorporate these digital technologies into the workforce of the future:

The online world has redesigned communication in and outside the workplace; anyone can access almost anything about a topic, so [young people] are now accustomed to accessing multiple open sources of information for solutions. As a result there are more collaborative technologies that have enabled the learning process to evolve from a fixed series of discrete training events into an informal, ongoing experience. Learning can easily occur anytime, anywhere and in a variety of formats. (p. 3)

Digital technologies thus offer the potential for different forms of learning and teaching where academic staff and students can change or transform their perspectives and meanings. The “push-pull” architecture of the Internet invites participation, generating symmetry between production and consumption which is not evident in traditional “broader-casting” mediums such as television or traditional models of formal learning. Tools such as wikis, social networking software (e.g., Facebook), and aggregator services (sites which bring together artefacts from other places) are identified as how educators might shift the emphasis of their teaching by empowering the student to see themselves as knowledge co-constructors rather than passive recipients of information provided. In an era when knowledge is no longer fixed and is subject to challenge on the very public platform of the Internet, students need the skills to explore and synthesize data to determine knowledge and construct meaning.

In this emerging digital age, models of learning based on behaviorism, cognitive, constructivist, and co-constructivist approaches are being overtaken by *connectivism*, an approach first offered by Siemens (2009). Connectivism defines learning as a continual process which occurs in different settings, including communities of practice, personal networks, and work places and allows teachers to shift focus from their textbooks and presentation to the actual student. Knowledge is emphasized by this theory, which stresses the

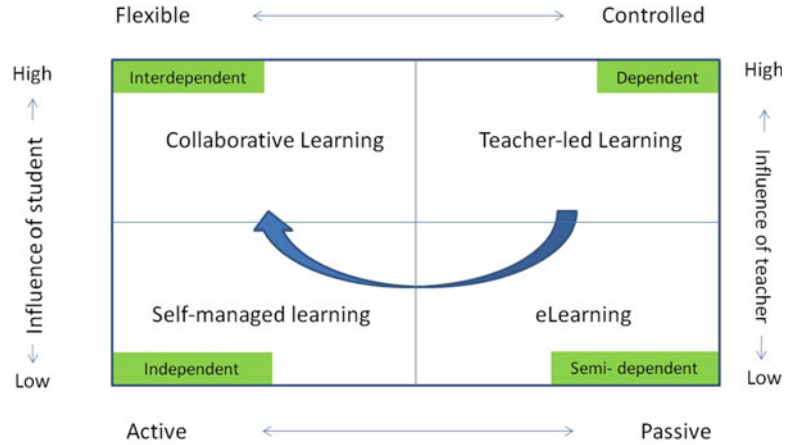
need to help students gather, access, synthesize, and publish knowledge in print or in online media. This knowledge is no longer under the control of experts, but has been distributed and is accessible to average students. In connectivist-based learning, the role of the teacher changes from that of providing material and presenting lectures to one of helping students create, publish, and share knowledge using Internet-based technologies. Consequently, connectivism suggests giving the learner the control to explore objectives defined by that learner. To facilitate the interaction both synchronous and asynchronous tools are essential as extensions of course environments. With connectivism, active participation is required by all involved in the learning process and matches the aspirations offered by Confucius: “Tell me, and I will forget; show me, and I will remember; involve me, and I will understand.”

Based on the above discourse, we devised a model which seeks to guide learning in higher education beyond self-managed learning and, in this instance, an approach to student learning that makes full use of digital technologies (see Fig. 1, below). As Crook (2008) indicates, the learning process in higher education requires greater self-management of learning as students progress from entry stage to graduation and on to postgraduate level and, in a digital age, engage with fellow students in a collaborative mode. We argue that in addition student learning potential will be enhanced by use of digital technologies that are now readily available and foresee the ultimate aim of such education as being the creation of effective learning environments through interdependency, a state often seen as ideal in the world of work where problem solving and creativity are the product of collaboration rather than independent contributions as suggested earlier (Helfand 2013).

Interdependency is highly valued in the workplace where, within a couple of decades, the tools used in most occupations will be replaced by digital ones (Organisation for Economic Cooperation and Development 2015) and in situations where it is essential that “young people can demonstrate that they not only possess knowledge demanded by employers, but that they can *apply*

Digital Technologies in Higher Education, Learning Challenges,

Fig. 1 Learning in a digital age – Alhafeeri and Male (2015)



that knowledge in different and unfamiliar circumstances” (Mann and Huddleston 2015: 7: original emphasis).

Use of Digital Technologies in Kuwait University

In a previous study, students and faculty teaching staff from the College of Education in Kuwait University were surveyed to assess their access to digital technologies, their capability to use them effectively in support of achieving planned learning outcomes and the implications for change that could emanate from such findings (Alhafeeri and Male 2015). Kuwait University is comparable to other institutions of higher education across the world in that most student learning is organized around face-to-face taught sessions with an expectation that students will undertake further study as appropriate in noncontact times. The organization of student learning in the university tended to follow traditional models, therefore, with academic staff presenting knowledge for student consumption via lectures, seminars, and directed reading. While there was widespread use of computer technology in the university in terms of support for learning, this equipment typically was only used for presentation of material during taught sessions or as a repository for materials through use of a virtual learning environment (VLE). Meanwhile most members of the

university had ready access to digital technologies, particularly portable hand-held devices capable of Internet connection, and were very capable of using them in a personal capacity.

Interestingly, academic staff not only exhibited a higher level of ownership of personal mobile digital devices than the student body, but also perceived themselves to be at least as capable as students in the use of such equipment to support teaching and learning in the college. Students, on the other hand, expressed doubt on the claims made by academic staff of competency and regularity of use of computer technologies in support of learning. A typical taught session, they claimed, consisted of lecturing and discussion without use of technology. The truth seems to be that while academic staff may be skilled and competent in the use of technology at a personal level, it was still not used extensively in face-to-face learning. Furthermore, use of personal devices was not allowed during lectures, even for Internet searches for relevant materials. The scenario witnessed in Kuwait is almost certainly mirrored across the world’s universities.

Discussion and Conclusions

Our previous work suggests that in the current era, higher education academic staff and students are well equipped with personal mobile digital devices and generally consider themselves to be

competent users of such equipment and associated software applications in their personal life. There was little evidence, however, to suggest extensive use of digital technologies to enhance student learning, often with the use of portable digital devices being actively discouraged in taught sessions.

The conclusion to draw from our study in Kuwait University is that ineffective use of available digital technologies is probably more to do with attitude rather than lack of opportunities. The findings from that study seem to mirror the situation that seemingly permeates all phases of education globally in that the technology exists, as does the capability to use it, but the willingness to exploit personal mobile digital devices and associated software applications is limited. The source of such limitation is typically based around intransigence of teaching staff to adapt their practice, a response often disguised through concerns about student safety and the validity of data sources when using the Internet (see, for example, Male and Burden 2014).

As discussed above, however, the potential use of digital technologies in higher education is evolving rapidly and, in the light of globalization and employability, this introduces an imperative for review and change of personal practice and organizational structures to accommodate new possibilities. Higher education institutions in the twenty-first century will need to adapt their strategy and policy regarding student learning to accommodate greater use of personal mobile digital technologies not only because they exist, but also in recognition of the opportunities to provide deeper, collaborative learning among students in the quest to further knowledge. Higher education should not be immune from such influences but will need to take suitable action soon if it is to fulfil its ambition to provide its student body with the knowledge and skills to operate successfully in the digital era.

Cross-References

► [eLearning in Saudi Arabian Universities, Toward Blended Learning](#)

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Digital Technology

► [Teacher Education, Thinking About ICT](#)

Digital Technology in Education

► [Information and Communication Technologies' Pedagogical Affordances in Education](#)

Distance Education

► Flexible and Distance Learning

Distance Learning

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Synonyms

Communication technologies; Computer-assisted learning; Computer-based training; Educational technologies; Information technologies; Instruction; Learning; Technology; Web-based instruction

Introduction

Distance learning, as a label to describe the use of educational and information technologies for instruction and learning, suggests a shortcoming either in the way that the instruction is conceived and delivered or in the appropriateness of the instruction for learning by qualifying “learning” with the adjective “distance.” Were traditional or conventional classroom-based instruction described as, for example, “co-locational learning,” we might be tempted to focus on how learning is influenced specifically by material artifacts such as table and chair arrangements, lighting, ambient distractions, student-to-student proximity, and so on. While these are issues that are worth studying (and are indeed published in journals such as *Learning Environments Research*), they have been regarded as given aspects of learning environments. More contemporary technological interventions to our learning environments, namely digital but prefigured by analog forms, that remove them from material and temporal constraints of classroom-based delivery remain the qualified learning

environments. And perhaps this remains a reasonable arrangement as the complex of instructional considerations we need to consider when thinking about how distance learning differs – though never fully departs – from what we might call traditional classroom learning environments.

Undermining the implied shortcoming of focusing on geographical distance and the tendency to stress the difference in time and place that often marks distance learning, Moore (1992) highlights what he calls “transactional distance” rather than geographic distance, defining transactional distance as the space between learners, instructors, and the instructional design of a course. Transactional distance can either be large (high structure and low dialogue) or small (low structure and high dialogue). Therefore, the transactional distance of a lecture-based face-to-face class, with limited classroom discussion, is larger than that of a tutorial between an instructor and a small group of students facilitated by a cloud-based collaborative application.

This distinction will have important implications when we discuss the strengths and weaknesses of distance learning environments for learning and student engagement. Certainly, having instructors and learners co-located has important implications for learning, including physical proximity, the ability to share activities without technological mediation, the opportunity to actively engage learners and to access, in real-time, whether they are learning or understanding the materials being discussed, and so on. But in other respects, being located in the same place at the same time may not be critical to all types of student engagement. For example, a group of four students tasked with collaboratively writing instructions, whether in class or online, are likely to employ some of the same cloud-based collaborative tools, such as Google Docs, to share, write, and manage their project.

This entry begins with a brief history of distance learning in Canada and the USA and traces some of the developments that have led to its growth over the last several decades. We then discuss the many ways that distance learning is and has been described over the years. One of the challenges with understanding what distance

learning is and is not lies in understanding how researchers label distance learning and how they have traditionally described it. We then review five dimensions of distance learning – of all instructional situations, in fact – describing what research tells us about designing effective instruction. Finally, we describe distance learning and some principle challenges yet to be addressed, touching briefly on massive open online courses (MOOCs) and discussing the importance of that technical trend for education in general.

The History of Distance Learning in Canada and the USA

The history of distance learning is often divided into four stages, beginning with print materials and early efforts with radio and television (the audiovisual stage, 1940s and 1950s). Correspondence courses started in England at the University of London in 1858, with its External Programme (Rothblatt 1988), and Bastiaens and Martens (2000) identified the existence in Germany, in 1840, of correspondence courses on stenography. Distance learning was initially described as correspondence, extended, or distance education and began in Canada several decades later at McGill University in 1889, followed in 1912 by the Universities of Alberta and Saskatchewan who provided “self-study programs” primarily for rural learners dispersed across the Western provinces (Haughey 2013). Distance learning programs in the USA date back to 1892 when the University of Chicago and Penn State University developed their correspondence programs (Pittman 2003). The second stage involves the incorporation of audio and video teleconferencing and the third stage focuses on computer technology capabilities, although the computer is generally standalone with floppy and compact disks (the instructional technology stage, 1980s to mid-1990s). There are, however, some antecedents, such as distance learning materials that were provided via radio broadcasts in 1941 when the Federation of Agriculture, the Canadian Broadcasting Corporation (CBC), and the Canadian Association for Adult Education created “Farm Radio

Forum” for use by home-based study groups that were organized by St. Francis Xavier University and shared with universities nationwide. Later, combining print with audio- and video-conferencing, distance learning expanded in the 1960s and 1970s to reach learners in remote locations, and in 1972, Athabasca University was created to provide distance courses via an open learning system (Haughey 2013). The fourth stage, our current one (the internet stage, circa 1994), involves cloud-based learning management systems with sophisticated course facilities for grading, building learning materials, sharing external resources, assessing student progress, and so on (James and Gardner 1995; Peters 2003; Wisher and Curnow 2003). Numerous historical factors have led to the exponential growth of distance learning over the last two decades. Most importantly, the decreased cost of information and communication technologies has increased user access to advanced collaborative environments. User expectations have also demanded not only that isolated users have access to educational learning opportunities but also that they be accessible at home and in the user’s workplace (Naidu 2003). Unfortunately, some negative forces are also increasing the number of universities in the USA who offer online courses and programs, for example, increased university enrollments, higher tuition costs, and state budget freezes. Despite such problematics, distance education does increase access to educational offerings for some students (e.g., working and older students) and other students are interested in the flexibility of online courses even if those students are located on-campus and have access to on-campus classes (Allen and Seaman 2016). Indeed, distance learning has only begun to capitalize on global audiences able to benefit from its time and location flexibility and lower student cost (Zhang et al. 2004).

Describing Distance Learning

Distance learning has numerous synonyms with varying definitions. Descriptions include online teaching and learning, web-based training, e-learning, computer-assisted learning, online

learning, technology-enhanced instruction, computer-based training, online teaching, flexible learning, distance education, open learning, and instruction and learning with technology. Why are there so many ways to talk about distance education? Many of the different terms used to describe distance learning are merely tailored for different audiences and contexts. After Bernard et al. (2004b), we view distance learning as involving three elements:

- Semipermanent separation (place and/or time) of learner and instructor during planned learning events
- Presence of planning and preparation of learning materials, student support services, and final recognition of course completion by an educational organization
- Provision of two-way media to facilitate dialogue and interaction between students and the instructor and among students (p. 388)

These elements, in turn, have influenced the features of modern learning management systems. Chapman (2005) summarizes these features as consisting of:

- Ability to coordinate course registration, scheduling, learning programs
- Resource management, content integration, repositories
- Material distribution, reporting
- Online conferencing, collaborative tools
- Tracking student accomplishments, learning assessment, learning testing, profiling (pp. 1151–1152)

Bernard et al. (2004a) analyzed and assessed distance learning literature from 1985 to 2002. After examining over 5,000 abstracts, 862 articles were gathered using electronic and manual searches of distance education journals and conference proceedings as well as reference lists of prior distance education reviews. The authors performed the searches using terms such as “distance learning,” “virtual university,” or “distance education” in addition to one of the following: “lecture,” “traditional,” “face-to-face” or

“comparison” (pp. 178–179). Of the articles found, only approximately 25% (232 articles) involved both traditional and distance learning conditions and connected to student achievement, retention, or attitude measures.

With the number of definitions, aspects of technology, and variables at work in distance education environments, it is not difficult to understand there are many challenges to understanding the nature of distance education in toto. Further to the challenges of identifying and defining distance learning, researchers have also identified methodological quality issues such as a high variation in effect sizes.

Orrill et al. (2004) argue that “Literally thousands of studies related to computers and learning have been published during the past three decades”, which poses a significant challenge, they tell us, to those interested in “making sense of the enormous, and growing, body of available research” (p. 335). Berge and Mrozowski (2001), in their review of research in distance education during the 1990s, found that almost 75% of the research involved descriptive studies. So too Nichols (2003) has lamented that “the vast bulk of literature in eLearning is practice-based and is typically presented in a descriptive format” and that “the body of literature appears fragmented and there are few common terms used consistently” (para. 2). In addition to applying inconsistent terminology to their objects of study, researchers have frequently performed comparison studies between online and face-to-face courses although just what constitutes an online course is not always the same (Allen et al. 2002; Álvarez and Kilbourn 2002; Berge and Mrozowski 2001; Bernard et al. 2004b; Larreamendy-Joerns and Leinhardt 2006; Liao 1999; Mehlenbacher et al. 2000). These comparisons have tended to emphasize student performance (determined by course grade) over other interesting issues such as environmental support for collaboration, heightened student engagement and motivation, influence of instructional design and usability, and so on. Even comparative analysis across distance education or e-learning approaches is challenged because, as Pascarella and Terenzini (1998) note, information

technologies are changing at such an accelerated pace that it makes studying them difficult due to the number of variables introduced: “The range and volatility of instructional information technologies not only present serious research design problems, they may also produce a fragmentation that will put knowledge development itself at risk of bogging down in a flood of studies based on single course, single learning settings (let alone single institutions) which have few characteristics in common whether in their independent or dependent variables” (pp. 161–162). Straus et al. (2006) too found that many studies of distance learning were methodologically limited, with small sample sizes, low response rates, convenience samples versus random assignment, and so on, a finding which they noted had been observed by other researchers (e.g., Phipps and Merisotis 1999). They found, additionally, that courses described as distance learning contained very different levels of media use, including one-way versus two-way tele-training, chat and asynchronous support, self-study versus collaborative group support tools.

Still, in the final analysis, many researchers appear to agree that distance learning is similar or comparable to traditional instructional contexts. Shachar and Neumann (2010) provide this summary after their meta-analysis of 125 distance learning studies, noting cautiously that distance learning occasionally outperforms traditional instruction as well and that this finding complements previous research (e.g., Bernard et al. 2004; Davies et al. 2010; Means et al. 2010; Newlin et al. 2005; Pang 2009). Notably, despite evidence suggesting that distance learning leads to higher learning outcomes (e.g., examination scores or course grades) and engagement in students, researchers often go out of their way to avoid challenging the primacy of traditional instruction. Erdogan et al. (2008), for example, conclude “This kind of interpretation would not mean that web based instruction is an alternative to classical instruction but web based instruction is an alternative solution to the education problem. . . .” (pp. 42–43).

In these discussions, the distance in distance learning remains a central focus for discussion. However, drawing attention away from the

technologies that mediate our learning environments for a moment, we can shift our vantage to explore some other attributes that shape these learning environments. In order to focus on the *learning* in distance learning, it is useful to describe in detail the five dimensions of distance learning, or of any instructional situation in fact, to help us attune ourselves differently to distance education environments.

Five Dimensions of (Distance) Learning

If we acknowledge that distance learning has less to do with the geographic distance between instructors and learners, as Moore (1992) allows us to do, then we can begin to see distance learning as a particular kind of instructional situation, admittedly one that relies on a technology-augmented connection between instructors, instruction, and learners.

The five dimensions of all instructional situations are learners (who have particular cognitive, biological, affective, socioeconomic, and material attributes), tasks (analyze the poem, combine these liquids, solve this physics problem), social dynamics (listen to a lecture, discuss the readings in small groups, debate two sides of an issue), instructional activities (learning objectives, rubrics for performance, methods for evaluating learning), environments (lecture halls, study halls, seminar rooms, labs), and artifacts/materialities (chairs, laptops, smartboards, scientific equipment) (Mehlenbacher 2010).

And just as all instructional situations call for planning, bringing together external resources that augment learning, establishing clear criteria for implementing instruction and for measuring learning outcomes, so too must instructors attend carefully to some of the marked differences between teaching at a distance and teaching in a face-to-face environment with little or no technology beyond traditional pencils and paper, tables and chairs, and whiteboards. Online instruction, importantly, transforms and reorganizes space and time and the classroom, at least traditionally speaking, feels as though it has disappeared initially.

Learners, Their Backgrounds, and Their Knowledge

Learners are perhaps the most studied of the attributes of any instructional situation, online or off. If we chose, instead, to focus on teaching methods or technological innovations employed in the classroom, we run the risk of de-emphasizing the central goal of any instruction, that is, to facilitate learning.

Research highlights that the background and knowledge our students bring to the classroom strongly influences how easy it is for them to learn new material, integrate it with their existing understandings, and apply what they have learned in new contexts. Importantly, anticipating our learners, their backgrounds and prior knowledge, self-regulatory skills, communication skills and readiness for learning is critical to the design of effective instruction. Moreover, how we account effectively for student diversity and difference is certainly a research area that requires additional attention, especially given the increasingly globalized learning audiences that instructors routinely interact with. We can now anticipate learners across the lifespan, with a range of cognitive and physical abilities, and different motivations, styles for learning, and metacognitive orientations. Different learners will meet new instruction from different understandings of the domain in study, with a range of skills and anxieties related to technology, and different textual and visual information capabilities.

An effective distance learning environment will tend to be highly goal structured, with instructors paying careful attention to student learning processes and progress throughout the course. The challenge with online courses is that learners need to be more intrinsically motivated than students in face-to-face settings where set scheduling, collegiality, instructor presence, and environmental proximity all contribute as extrinsic motivations. Hiltz and Shea (2005) found that students who have a strong internal locus of control (feeling able to accomplish their goals online) and who feel positive about their technological abilities, in addition to participating regularly in distance learning courses, tend to do better than

students who are more passive or disengaged. Naturally, instructors will need to establish whether learner passivity is a feature of poor instructional design or a motivational issue that resides in the learner.

Learning Tasks and Activities

Tasks designed to teach students not only *how to do* something (e.g., write an essay) but also to teach them *about* something (e.g., history of ancient Greece) are often ignored when researchers talk about designing instruction. One of the reasons that learning tasks tend to receive little attention in higher education is that procedural knowledge tends to be left to training and, in higher education, instruction is designed to focus on epistemic matters. Another reason that tasks may receive less attention than they should when we think about teaching is that many instructors are not very good at explicitly setting learning objectives for their students and their instructional materials. Researchers such as Bloom (1956) and Biggs (1999) provide useful ways of thinking about instructional learning objectives (which can move from comprehension, application, analysis, synthesis, through evaluation or identification, description, analysis, through theorization). Learning objectives explicate instructional goals using specific language that can be measured for success or failure. Students will be able to describe, evaluate, compare and contrast, apply, differentiate, and so on. And, in turn, instructors can then measure whether their students have learned to do these things or tasks.

Properly conceptualized, learning tasks and activities ultimately unite learner behaviors, facilitate social dynamics both online and off, inform instructional activities, and clarify what types of assessment are most effective given the assignment deliverables. For this reason, many instructional designers strongly recommend that learning tasks and activities be as authentic to specific contexts as possible. Moreover, after Herrington et al. (2003), it is critical that instructors design learning tasks that are as authentic to the skills and knowledge they hope learners will master as

possible. Authentic tasks and activities are connected to real-world activities, are ill defined or complex, facilitate seeing issues from different perspectives, highlight collaboration, and can have different outcomes and competing solutions.

An effective distance learning environment will have well-designed content and, particularly, clear instructions and an easily accessible schedule for completing instructional tasks and activities. Instructional content that highlights not only what instructors expect their students to learn but also provide opportunities for learners to synthesize and articulate covered materials also help students develop their metacognitive strategies.

Social Dynamics in the Digital Classroom

Allen et al. (2002) used the search terms “distance learning,” “distance education,” and “satisfaction” on SocioInfo (Index for the field of Sociology), ComIndex (communication publications), Psychlit (psychology publications), and the Educational Resource Information Clearinghouse (ERIC), in addition to conducting a complete review of *Distance Education* and the *American Journal of Distance Education* to identify approximately 450 peer-reviewed articles for analysis. Although their primary goal was to compare distance learning courses to conventional ones, the authors also identified several research themes that characterized the corpus of articles under review. Topics reviewed included the effects of the modality of communication (video, audio, and written) and of the presence or absence of interaction in setting (none, one-way limited, or fully interactive). Not surprisingly, Allen et al. (2002) found that the greater the channel of communication and instructor-student interaction, the greater the effect on student satisfaction.

An effective distance learning environment will provide alternative forms for communicating collaboratively with other students and also for supporting communication between instructors and learners. Importantly, online materials must be well designed and goal- or criterion-directed, employing thoughtful sequencing (from simple to complex instructions), encouraging easy response

and quick feedback, in addition to some elaboration and exploration on the part of learners. Although tools for collaboration abound, many instructors new to distance learning forget that online learners tend to feel somewhat isolated in their learning and long for meaningful interactions that increase their sense of belonging in a learning community. Collaboration tools that support both synchronous and asynchronous interaction heighten learner belonging and, by default, contribute to students who engage the materials more deeply and who rely on other learners in the instructional situation as well as the instructor.

Instructor Activities

Instructor activities with distance learning involve all planning, implementation, design, testing, and assessment efforts built into a course to help motivated and engaged learners manage their learning experience. Students who are not motivated to learn or who have limited experience working online are likely to focus on surface learning activities (e.g., where are the readings, what activities are due, where are they described, and what resources are available to help meet the course expectations). Instructor beliefs, knowledge of the subject matter, experience of teaching online, the amount of instructor presence they are able to present, and thoughtful feedback they are able to provide all contribute to online learners' engagement with online instruction.

Successful online instructors tend to operate more as consultants or facilitators for their students, guiding them as they encounter new information and processes and, importantly, orienting them to the opportunities and challenges of learning online. Critical to online learning is the creation of a safe learning environment where students are encouraged to work cooperatively and collaboratively with others (Bonk and Dennen 2003), in discussion lists, shared posts, collaborative projects, and in sharing class expectations and processes with others. Although many instructors have limited training in how to integrate visuals into their textual instructions, research suggests that visuals are powerful learning aids. Schnotz

(2005) suggests that instructors thoughtfully build coherence and continuity into their modular instructions, taking care to design their materials to anticipate different learner reading ability and prior knowledge about the course content (pp. 60–63).

Notably, even experienced face-to-face instructors may require some training before they can effectively transfer to distance learning instruction (Petherbridge and Mehlenbacher 2007). This is not entirely surprising given the host of knowledge that most instructors need to bring to any teaching situation. Not only must instructors have some expertise in subject matter and in pedagogy, but they must be sensitive to what the research tells us about how students learn and also about how online instruction influences and undermines traditional models of instruction. Online, for example, learners are much more likely to become disoriented and disengaged if they do not hear back from instructors regularly; moreover, learners tend to skip and scan online information much more than they do print materials (Mehlenbacher 2003). Instructors also need to understand not only how to facilitate discussion and written discourse but also how to manage instruction and course sequencing online; many of these activities in face-to-face instruction are tightly integrated with classroom discussion but, in distance education, must be attended to as well. Summers et al. (2005) found, for example, that the same instructor teaching online and face-to-face classes received lower satisfaction ratings online for the usefulness of the instructor's explanations, and the instructor's enthusiasm, openness, and interest in student learning (p. 244). Hale et al. (2009) add to this finding, noting that online students found their instructor's established rapport and personal interest in them was lacking. Distance learning alters the response that learners have to behaviors that are almost identical except for whether they occur in a classroom or online. For this reason, online instruction benefits immeasurably from careful presentation of content and questions, efforts to focus instruction, attention to student contributions, summaries, and well-articulated assessment and feedback.

Learning Environment and Artifacts

A number of challenges with distance learning that are difficult to manage relate, expectedly, to technological design: screen resolution, display area, and aspect ratio all contribute to different levels of engagement and learner receptiveness (Selber et al. 1997). Print literacy has a considerably longer history than computer-based information and the accelerated rate of display options and sizes is influencing learner reading and writing patterns in ways that are difficult to anticipate, and in ways that seem to be evolving.

Additionally, even powerful learning management systems are constantly evolving and integrating new tools and processes. Iverson (2000), in describing typical classroom contexts, notes the effective classes *place*, that is, learner location in classes, groups, around tables, face-to-face or adjacency, individual and shared workspaces, and so on. Conventional classrooms are equipped (with computers, whiteboards, work arrangements, and structure), and they encourage spatial reconfiguration and learner movement. Finally, conventional classrooms employ well-developed modes of communication, oral, structures, dialectic exchanges, and summarizing. These are elements that must be designed and built into distance learning spaces.

Most importantly, distance learning operates in several potential modes on a continuum from on-site learners and on-site facilitation and support, through on-site activities and virtual support, virtual activities and face-to-face support, through fully digital display, discussion, and interaction. In the middle of the continuum, instructors operate in blended environments and the research on these environments is only beginning to outline the strengths and weaknesses of working in these developing structures (Van Eijl et al. 2005).

Finally, Bransford et al. (2000), Bereiter (2002), Jonassen (2008), and Mehlenbacher (2010) highlight the transformative power of technology to enable, extend, or augment professional activities, genres, and artifacts. Various described as cognitive tools or conceptual artifacts, these tools extend human abilities to design, predict, analyze, and present artifacts demanded

of them by their professional transactions and practices. Cognitive tools do not replace previous print-based objects with digital ones (e.g., books as portable document files) but, instead, shape and extend existing activities in new ways (Weston and Bain 2010).

Paying Attention to Distance Learning

The landscapes for distance learning are changing in ways that are difficult to predict with consequences that are even harder to anticipate. Dutton and Blank (2014) note, for example, that between 2003 and 2011, the percentage of British online publics who used their smartphones or tablet devices to access the internet had jumped from approximately 10% to 50%, similar to growth statistics for the USA, which has 95% of Americans using smartphones, up 35% since 2011 (Pew Research Center 2018a). In addition, more and more households boast higher broadband connections suggesting that the need for reliable, high speed internet access has increased over the last decade and is viewed as “essential” (Pew Research Center 2018b). Yet interestingly, current internet users are much more likely to access the internet while on the move or outside of work or the home; alternative locations for access include another person’s home, the library, in an internet café (all cafés, now, essentially). What the implications are for a learner population that accesses distance learning materials on the move, between locations and, frequently, while multitasking or engaged in an additional task, remain unclear.

In addition to the attentional difficulties of reading on the go, researchers have identified numerous information processing challenges that include fatigue and multitasking in addition to the influence of different sizes of displays and font sizes. It is also well documented that internet activities can amplify cognitive errors; for example, confirmation bias where users tend to find support for their own points of view and group-think, where individuals tend to follow members of the group (Tarkoff 2018). Moreover, students asked to engage others in open-ended discussions of course subject matter tend to offer surface level

contributions that reach agreement (i.e., “good post!”) rather than providing elaboration, taking issue with contributions, or questioning the positions taken by their classmates. Some of the hesitation to contribute authentically or to facilitate lively discussion can be traced to the seeming permanence of written contributions (in contrast to oral give-and-take) and some has to do with the user sense that posting is a one-way activity without a face-to-face audience to engage with. Another aspect of this challenge might be that students are merely satisficing, that is, doing what is minimally required to engage with the instructional situation. This is a natural inclination on the part of learners, particularly online learners, and must be addressed actively by instructors who are virtually present and engaged with learner discussions and contributions.

And then, 2012 became “The Year of the MOOC” (Pappano 2012), which described the conception and popularity of what was described as a “campus tsunami” that represented the future of the educational system (Leckart 2012). MOOCs, or massively open online courses, promised to democratize education “bringing quality learning content to people of any age, in any corner of the world for a fee – if not for free” (Brooks 2012). Coined in 2008 by Dave Cromier (University of Prince Edward Island) in response to an online course designed by George Siemens (Athabasca University) and Stephen Downes (NCR Canada), the first MOOC involved 25 tuition-paying students at the University of Manitoba and 2,300 general students who took a “Connectivism and Connective Knowledge” class for free (Downes 2008). The course interactions consisted primarily of Rich Site Summary (RSS) feeds, Moodle discussions, blogs, and 2nd Life synchronous online meetings, technologies that all existed and were regularly used at the time to reach unprecedented numbers of students and, most importantly, MOOCs brought discussions of the role of distance learning in higher education to the public conversation. Moreover, MOOCs attracted a lot of funding (from the William and Flora Hewlett Foundation, the Andrew W. Mellon Foundation, the Bill & Melinda Gates Foundation, and Google), all poised to capitalize on

what was seen as a transformative trend in higher education (Kolowich 2012; Weissmann 2012).

But the bubble broke, or at least it appears to have deflated considerably. And part of the reason why can be determined by looking at the history that led up to the educational online revolution. During the 1980s and 1990s, American universities had increasingly privatized and, as the professoriate dropped, universities saw a sharp rise in adjunct or contingent instructors. In addition, universities were increasingly under attack for being too expensive and for serving the student population poorly (Bousquet 2008; Hoeller 2014; Wallerstein 2012). MOOCs appeared to offer unprecedented opportunity for learners who otherwise could not afford to attend Ivy League universities, even though their retention rates were often as low as 5% and their pedagogical structures were rather traditional (e.g., web course materials, audio- and video-based lecture recordings, student-driven assignments and participation, and auto-grading or peer review-based assessment). Critics began to highlight these issues and to note that MOOCs reinforced the hierarchy between students who can and cannot afford the on-campus experience. Moreover, MOOCs inadvertently supported the critics' belief that education should continue to be defunded, stressing credentialing as the primary mission of universities. Finally, MOOCs continued to serve the growing adjunctification of university instruction, running the risk of further reducing student-faculty interaction, a cornerstone of campus education.

It is problematic to conclude that MOOCs are a failed distance learning enterprise, but initial promises that they will reshape education in total are exaggerated and unsupported. MOOCs are designed to have high transactional distances between instructors and an enormous number of learners (cf., Moore 1992), a pedagogical structure that is similar to learning from large lecture-hall classes with breakout study groups. Although these structures can certainly lead to successful learning experiences, researchers have found that high transactional distances limit student

engagement and learning (Bolliger and Halupa 2018). Many MOOCs, therefore, are not revolutionary pedagogy. In addition to studying the sociotechnical context that is informing the design of online and conventional instruction, future researchers will want to extend their studies of learners to include informal learning contexts and international learners as well as how socioeconomic issues influence the teaching and learning that students encounter and experience.

Cross-References

- [Assistive Technology and the Gifted Learner](#)
- [Computer-Assisted Instruction, Changes in Educational Practice as a Result of Adoption of ICT](#)
- [Computer-Assisted Learning](#)
- [Computer-Based Training and School ICT Adoption, A Sociocultural Perspective](#)
- [Flexible and Distance Learning](#)
- [Formats of Virtual Learning](#)
- [Online Teaching, Emotions, and Emoticons in Computer-Mediated Communication](#)
- [Problem-Based Learning Online](#)
- [Teaching with Computing, Educational Games](#)
- [Technology Enhanced Learning](#)

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Distributed Collaboration in Project-Based Learning and Its Assessment in Next-Generation Learning Environments

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Introduction

Distributed Collaboration in Project-Based Learning and Its Assessment Advances in technology historically have altered the ability of individuals to communicate with and to collaborate with one another (Hollingshead et al. 1993; Walther et al. 2015; Liao et al. 2018). The implications and opportunities for education have been and will continue to be profound (Collins and Halverson 2018). This entry introduces the nascent area of IT-mediated collaborative learning activities that focus on creating a product or an artifact and that involve virtual teams of individuals who work together, both synchronously and asynchronously, from geographically distinct locations (Hamilton 2018; Hamilton and Owens 2018; Lee et al. 2019). While contemporary society is accustomed to the anywhere/anytime nature of Internet-mediated communication, formal and informal education models have not yet substantially incorporated research-based approaches to virtual, project-based collaboration in differing geographic locations. While a later section notes some important exceptions to this generalization and furnishes a light taxonomy of collaboration forms, information technology has ushered in new forms of connecting students both through communication with each other and through the content of what they co-create.

This entry focuses on and advocates widespread adoption of such collaborations more broadly in the design of next-generation ecosystems, especially as they involve two additional

characteristics. The first is that the collaborations entail direct, interpersonal interactions between the geographically distributed participants, interactions that are incidental to the artifact itself. That is, the participants become personally acquainted, often forming friendships, usually over videoconferencing or other IT-enabled means. The second characteristic involves virtual collaborations that cross cultural, national, economic, generational, academic background, or linguistic boundaries. We refer to those here simply as boundary-crossing collaborations (see Niemi and Multisilta 2016).

The potential for such IT-mediated collaboration, including cross-boundary forms, to function as *a natural, abundant, and seamless aspect of next-generation school learning*, is intertwined with crucial and exciting technology-enabled areas currently unfolding in education research, innovation, and the learning sciences.

In the near term, these areas include the makerspace movement (Sheridan et al. 2014; Fontichiaro 2016), the ascendancy of both computational thinking (Paul 2016) and design thinking (Liedtka et al. 2013; Leinonen et al. 2014), more context and place-aware learning tools (Sharples 2015), project-based learning and modeling (Rouvrais et al. 2006; Tsai et al. 2015), triological approach for learning (Paavola and Hakkarainen 2014), and advances in education data science (Williamson 2017).

Over a longer term, current research in augmented and virtual reality (Dunleavy 2014), artificial intelligence and adaptive learning environments (Gerard et al. 2015), and more mature and sophisticated conventions on massive data capture and use will occupy more prominence.

The next section briefly discusses the growing emphasis on collaborative learning in education research before delving into the potential for virtual, project-based collaborative learning to occupy a prominent place in future learning environments. Such strategies for learning veer far from practices that lend themselves to traditional testing. The entry closes with a discussion of how computationally intense techniques adapted from social network analysis can be employed for settings such as collaborative project-based learning.

Such techniques can allow educators and designers to visualize student and team progress more holistically and across a range of heterogeneous indicators, including traditional indicators of academic performance but including socio-affective and cross-cultural growth, which are interrelated in project-based virtual collaboration and must be assessed in connection with one another using advanced data methods. Such IT-enabled innovations in learning analytics will permit more telling and interconnected pictures of how individuals and groups progress epistemically and of key malleable variables that shape their progress.

IT Mediated Collaborative Learning

The rationale for learning to be researched more fully as a social phenomenon, along with the construct of a joint problem space (Teasley and Roschelle 1993), has been widely accepted at least since the early 1990s. In addition to a theoretical rationale, the exploits or accomplishments of virtually every sector of society arise from collaborative activity (Hesse et al. 2015) and rightfully impels more attention to collaboration in primary and secondary education.

The term *collaborative learning* is subject to varying interpretations. For present purposes, we adopt the definition by Hennessy and Murphy (1999), who treat collaboration as referring to students “actively communicating and working together to produce a single outcome, talking and sharing their cognitive resources to establish joint goals and referents, to make joint decisions, to solve emerging problems, to construct and modify solutions, and to evaluate the outcomes through dialogue and action” (Hennessy and Murphy 1999).

The importance of IT-supported or computer-supported collaborative learning has been documented across academic domains, in part through high-impact visionary (e.g., Teasley and Roschelle 1993; Koschmann 1996; Roschelle 2013) and summative (e.g., Dillenbourg et al.

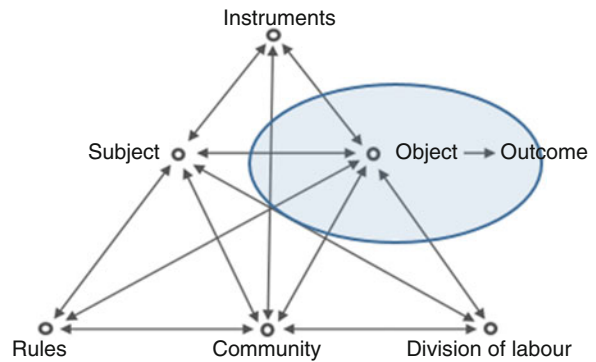
2009; Jeong and Hmelo-Silver 2016) (e.g., Dillenbourg et al. 2009; Jeong and Hmelo-Silver 2016) articles, including specific domains of school learning (e.g., McKeown et al. 2017). The research community emerging in the 1990s in computer-supported collaborative learning now holds biannual conferences and eventually created the *International Journal for Computer-Supported Collaboration* (iJCSCL) in 2006 (Stahl et al. 2006). That literature largely (but not exclusively) involves student collaborators, who interact in physical proximity, such as in a school, home, or museum.

Distinctions Between Project-Based Virtual Collaborative Learning Forms

Project-based learning in virtual or distributed collaborations is uncommon in primary or secondary education, with some exceptions. The emergence of wikis or other Web 2.0 social media forms in the 2000s fall somewhat outside this consideration of projects that represent defined tasks to jointly complete a project artifact. Internet-mediated project-based learning generally entails completing digital artifacts. Collaboration through second life was one of the earliest exemplars (Wagner 2008) of a family of applications involving simulations, virtual worlds scenarios, or their creation (e.g., Barab et al. 2005; Barab and Dede 2007; Dede 2009). Among the most prominent contemporary examples involve the collaboration forms for Scratch programming (Maloney et al. 2010) or for Minecraft (Müller et al. 2015; Niemeyer and Gerber 2015). Each of these examples, however, represent instances of where the product of the collaboration represents an artifact embedded in the digital context in which it was created, such as a virtual space or a wiki. Project-based collaboration in virtual reality settings will become more common in the near term and will also fall into this category (Greenwald et al. 2017). Each of these also can engage learners who can choose to remain relatively or virtually anonymous to each other.

Distributed Collaboration in Project-Based Learning and Its Assessment in Next-Generation Learning Environments,

Fig. 1 Cultural and historical activity theory schematic (Soegaard and Dam 2012)



Sharing Design Priority on Learner Community with Artifact Production

Adopting a cultural-historical activity theory (CHAT) framework may help to illustrate an important difference between collaborations situated within online containers (e.g., Minecraft or a virtual world) and projects meant to yield artifacts and to require more active interpersonal connections. CHAT depictions distinguish between the actors, actions, objects of actions, and conventions or rules of action. Fig. 1 schematic appears in various forms in social sciences literature (Greeno 2016) and functions well as an organizing or descriptive tool for group activities. A common premise of the learning sciences is that activity mediates learning. Rather than preceding or preparing for activity, in other words, learning—especially project-based learning, for example—is embedded in activity systems. Mapping Fig. 1 schematic to the IT-enabled project-based collaborations may help to situate collaborations where participants may remain anonymous or obscure versus a more active personal interactions role in co-producing team artifacts.

In the former case, the primary object of collaborative learning is the artifact. An alternate perspective is one in which the connections between the collaborators, i.e., the personal interactions and emergent community, are of equal or higher importance as an object of the collaboration (Hamilton et al. in review). In this family of collaboration types, strong dyadic and community formation share or exceed priority with artifact production as a collaborative goal or object of

the activity. Cross-cultural, international, ethnically diverse, or other boundary-crossing dimensions amplify considerations when designing such collaborations.

Interestingly, those dimensions may address an apparent shortcoming in virtual versus local collaborations. While virtual and local project-based learning may each be considered knowledge building through social interaction (Von Kotze and Cooper 2000), some researchers have concluded that virtual collaborations entail less robust social interactions than those that are local or co-located (Kreijns et al. 2013). One conjecture for this is that social and emotional factors such as trust, identity with a community, and interpersonal relationships that are at the center of face-to-face collaboration are less salient in virtual settings (Fischer et al. 2013). Indeed, collaborations that permit relative anonymity by participants, such as wiki contributions, Minecraft making, or virtual world communities, may entail active and intense interactions around the artifact but require little socialization or interpersonal exchanges. Collaborative scripting as a means to scaffold interactions has been the subject of a sizable strand of research in the CSCL community (e.g., Dillenbourg and Tchounikine 2007; Fischer et al. 2007; Strijbos and Weinberger 2010; Kreijns et al. 2013; Wang and Mu 2017), but that work primarily focuses on optimal designs to facilitate collaboration, i.e., is artifact-oriented rather than focusing on relationship building. In the CHAT framework, scripts have instrumental value to scaffold activity and progress toward completing

the artifact. An alternative direction is to create conditions that more explicitly scaffold relationships between participants, by which they transition from acquaintances to a blend of active friendships and collegial boundary-crossing (e.g., international) connections.

IT mediation, especially through videoconferencing for the synchronous aspects of the collaboration, has proven crucial in such participant-centered collaboration (Eagan and Hamilton 2018; Lee et al. 2019).

IC4 Project

Figure 2 depicts videoconferencing between students in four countries in research that the US National Science Foundation (NSF) supports through its *Advancing Informal Science Learning Program*. This research effort is called the International Community for Collaborative Content Creation or IC4 (ic4.site; Hamilton and Culp 2016). It involves digital media-maker teams of elementary through college-age students in five demographically distinct US locations, along with synchronous and asynchronous peer collaborators in Africa, Europe, Asia, and Mexico (Kallunki and Hamilton 2017; Hamilton and Owens 2018).

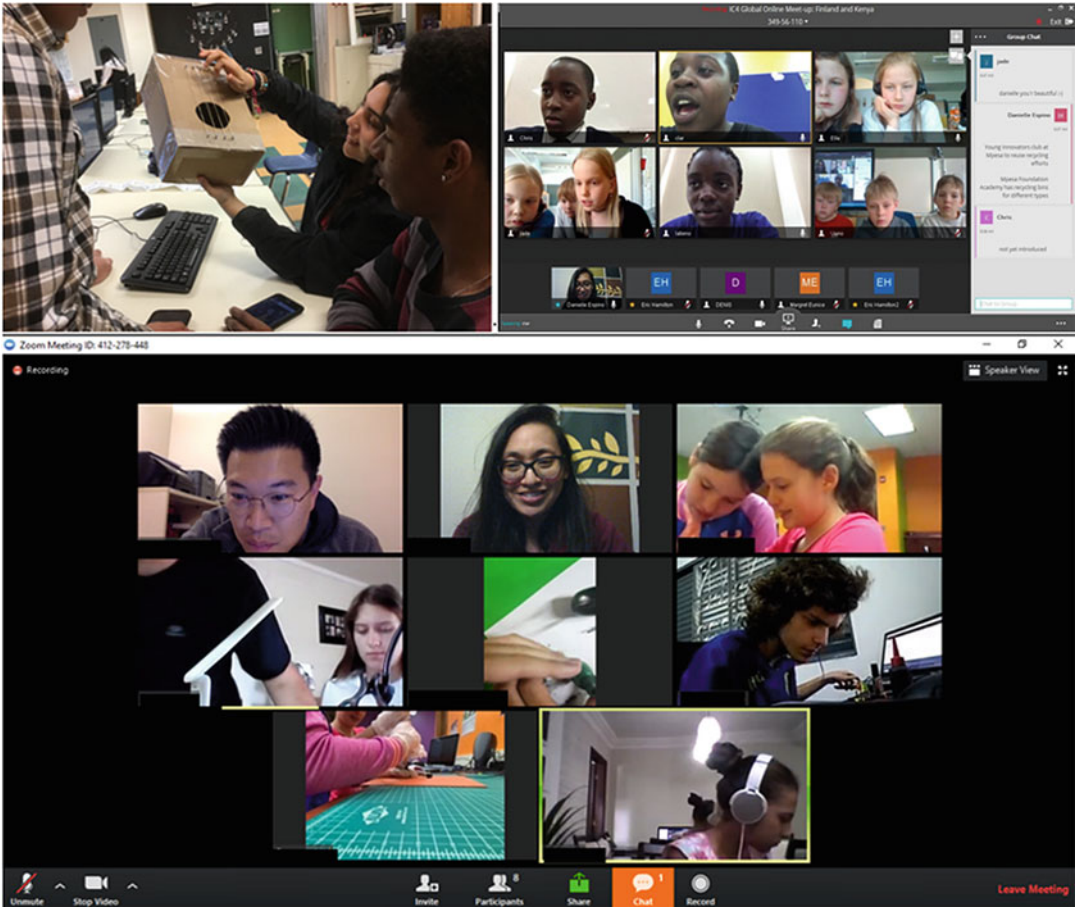
This type of diverse setting is one in which it is possible to investigate the conjecture that cross-boundary virtual collaborations can have robust social interactions that rival those of face-to-face collaborations. Research focusing on virtual teams confirms that knowledge-sharing and collaboration positively impact social trust (e.g., Erdem and Ozen 2003; Alsharo et al. 2017) in adult workforce settings. One conjecture we are testing at the secondary school level is that it may be that being able to observe and interact closely with a peer from a different culture, country, or economic stratum is non-threatening from the cultural safety of one's own location. It appears that collaboration from one's own home or school environment, for example, can effectively neutralize potential inhibiting anxieties, while trust and friendship relationships take form in completing a task. This primes and scaffolds new understandings about both the shared task and about one's peers. That sense of safety can help induce not

only comity but also deeper appreciation, joy, and celebration both of shared humanity and of the gravitational allure of instructionally well-designed projects. The field of boundary-crossing virtual collaboration in precollege project-based collaboration, at least as far as it prioritizes active interpersonal interaction, is relatively scarce, despite important work referenced above in the development and testing of collaboration scripts.

With the language and frameworks for this field still unfolding, the question of whether cultural safety from a distance neutralizes inhibiting anxieties that otherwise emerge in face-to-face settings is indeed still conjectural. Consistent with this possibility, however, we have found repeated confirmation of the existing finding that school-based collaborative learning can generate creative energy and distribute high-valence affect among its participants (Chua et al. 2012). IC4 participants, for example, such as those appearing in Fig. 2, repeatedly cite surprise and pleasure at meeting and interacting with peers from other cultures and nationalities (Kallunki and Hamilton 2017). The IC4 design prefaces any interaction between participants with self-introductory videos or online presentations each creates. Students meet each other virtually and share their interests, especially in the science, technology, engineering, or mathematics (STEM) areas that are the focus of their joint projects. These projects take several forms, and the virtual context in which the students collaborate are referred to as digital makerspaces (Hamilton and Culp 2016; Eagan and Hamilton 2018). These initially included co-constructed videos, and then video remixes using the online Sway platform, robotics projects, and coding.

MoViSTEM Project: Finland-USA

The IC4 project originates in part from a prior Finland-USA collaboration, called the Science Across Virtual Institutes (SAVI) network (Hamilton 2012). The SAVI network had 16 research projects in Finland and in the USA in an effort to carry out significant advances in education and the learning groups (<http://www.innovationsforlearning.net>) (e.



Distributed Collaboration in Project-Based Learning and Its Assessment in Next-Generation Learning Environments, Fig. 2 Boundary crossing: collaboration team in NSF-funded Informal Science Learning project (IC4), representing multiple ages, cultures, countries, and backgrounds. From top left: Students in a California school

making a stringed instrument and testing its octaves for sharing with partners in the USA and Kenya; students from Finland, Kenya, and the USA share a session on Scratch programming and videoconference work session with students in Brazil and USA

g., Rowe and Shernoff 2014). One project in this NSF, Academy of Finland, and Business Finland (earlier TEKES)-funded collaboration was a Mobile Video STEM Inquiries (MoViSTEM) project. MoViSTEM represents asynchronous online collaboration between students in the two countries generating digital storytelling that has been used as a part of science learning in comprehensive schools in Finland and the USA. In this project, small groups of students created digital stories by recording videos, uploading the clips to the online environment where the videos were edited, sharing them with others, and remixing them with

annotations. In this way the focus was both on sharing and learning. In the project, collaborative communities were formed at two levels: local communities in classrooms and global communities in the virtual environment. The global communities worked as small groups or pairs alike to mentoring pairs: high school students from the USA commented on and asked questions about the digital stories created by the younger Finnish students. The collaboration was organized as an asynchronous activity so that commenting happened generally on the day after the sharing of videos. Finnish students had positive experiences of community:

the feeling that someone “there behind the big sea” was watching and commenting their videos motivated the students. Being able to use English in a real context played a role in creating a positive view of collaboration. In addition, linguistic boundary crossing took place on both sides, since the Californian students wanted to communicate in Finnish and used Google Translate for this purpose. In general, the findings from the Finnish side indicate that an online collaboration including digital storytelling experience has an impact on the use of English as medium for international communication and the establishment of networking and collaboration with peers both online and locally (Vivitsou et al. 2017).

MoViSTEM Project: Sino-Finnish Collaboration

In a subsequent phase of the MoViSTEM project, digital storytelling experimentation was carried out between China and Finland (funded by Business Finland). The project connected four primary schools in Finland and in China (Vivitsou et al. 2017). This project, where classes of students from both countries created digital stories locally about shared topics, was also implemented in a form of asynchronous collaboration. After creating the digital stories, the students shared the stories in an online environment (edvisto.com), and the stories were then watched and commented on in both countries separately. In both countries watching digital stories from the other country has been welcomed with curiosity and excitement.

Other examples include schools that partner with area businesses to engineer solutions to real-world problems, Internet-based exchanges around robotics, and platforms for collaborative video and music authoring and mixing. Beyond specific examples, though, we envision virtual teams of students in next-generation school learning environments in settings similar to – and more sophisticated than – current workforce settings in which virtual, heterogeneous, distributed professional teams are commonplace.

Sociocultural Development and Academic Growth as Mutually Reinforcing

The domain of virtual team collaborations across cultural, ethnic, national, or other boundaries is extremely promising for next-generation school learning environments and for far-reaching social and economic well-being. Research suggests that distributed collaboration settings can foster both group and individual growth in areas such as self-regulated learning (Panadero et al. 2015) and group and individual problem-solving capabilities (Hmelo-Silver 2016). The intuitively sensible proposition that *group or team* collaboration can intrinsically contribute to social or intellectual maturing of the individual may be even more far-reaching, due to an equally intuitive finding that what we refer to as cross-boundary collaboration in schools can routinely generate socio-cultural and affective energy, performance motivation, curiosity, and social trust (Hamilton and Owens 2018; Lee et al. 2019).

In practical terms, these prosocial dynamics can materially contribute to individual intellectual rigor and academic achievement. Collaborative discourse implies intersubjective meaning-making, i.e., the formation of shared meaning (Suthers 2006). Learning that results from dialog and other interactions between collaborators entails designing, creating, and developing artifacts that challenge participants to learn more and to step outside their earlier proximal zone to a higher plane of quality (Multisilta 2014). That drives the need to clarify, retrieve, and build new knowledge. Collaborative discourse drives the cognitively powerful process of self-regulation and self-explanation (Crippen and Earl 2007; Mitchell 2009; Nokes-Malach et al. 2013), leading the learner to acquire the perspective of, and make sense to, the boundary-crossing collaborators (Lindgren 2009). In distributed and digitally supported collaborative environments, learners are both content producers and consumers. When creating project artifacts, students must not only isolate the most relevant content but also the most effective way to teach their peers through their artifact. They must assess critically,

give feedback, and validate the knowledge they find. This method allows or requires students to work together (Pea and Lindgren 2008; Lindgren 2009).

Collaboration benignly coerces participants to jointly represent, elaborate, test, expand, and refine their STEM thinking (Wong et al. 2002) at both the individual level and at the level of their social and distributed cognition. This extends self-regulation to its analog at the group level, socially shared regulation (Järvelä et al. 2015) – a construct representing a team analog to self-regulation, involving sizing up group tasks, identifying roles, knowledge needs, and purpose. It creates new channels for grasping, comprehending, sharing, and deeply integrating discovery, knowledge, and skills into a young person's early life experience and future expectations of self and society. It also reflects increased appreciation for the intertwined nature of socialization, affect, culture, motivation, and learning (Immordino-Yang and Damasio 2007). Cognitive and collaborative competencies reinforce each other in ways that create a forcefulness for personalized school learning (Spector 2014). This forcefulness is undertheorized, underdesigned, and underappreciated for its potency as an asset in the design of high performance and prosocial education for next-generation learners.

More generally, distributed project-based collaboration offers opportunity to the next generation to invent new conditions for interaction that are not defined by geography. An illustration that appears out of place may instead convey some of the potency of the distributed collaboration in ways that address fractures in our broader global society that fall too often along cultural and geographical boundaries.

Historical Perspective from the USA. One of the most contentious and difficult aspects of the civil rights movements in the 1950s into the 1990s in the USA has involved school desegregation. The physical relocation of students through forced busing reflected tools available to courts at the time to address the racial segregation norms in US schools. The record of the school desegregation enterprise was mixed, with multiple factors undermining success (e.g., Failer et al. 1993; West

1994; Wells et al. 2005). An important study at Columbia University, however, traced the socio-cultural experience of students involved in the integration effort, unpacking an importantly positive and often overlooked aspect of this entry of US history. Beyond the social strife surrounding physical relocation of students, a pervasive finding in the study involved the socio-affective and academic richness and growth experienced by learning alongside peers from different racial and economic profiles (Holme et al. 2005).

Designed to address economic inequality, desegregation action was ordered by courts with tools in education that were available at the time. But the tools for bringing students of different backgrounds together in learning, and to experience the cross-cultural and socio-affective richness that was once only possible through strife-riddled physical relocation, are different now. Virtual presence dramatically inhibits the power that physical geography has imposed to separate and instill distrust and conflict throughout our history. Virtual collaboration in project-based learning and artifact production will not replace court-ordered remedies to racial conflict. Coupled, though, with technology-enabled tools to foster interpersonal interaction, it will offer opportunity for almost unbounded replication and expansion of some of the most salutary effects of physically relocating students across boundaries.

Indeed, we have found in the IC4 project discussed earlier that developing communities of students who collaborate on projects virtually across cultural, economic, and national boundaries *routinely elicits a sense of cross-cultural curiosity and embrace* (Hamilton and Owens 2018). IC4 is a network of school-affiliated “digital makerspace” clubs in six countries, for middle and secondary students who collaborate in producing videos, robotics demonstrations, coding, or other digital artifacts that can be created and shared over the Internet. How each student expresses cross-cultural curiosity and embrace in this context varies by individual and their culture, but indicators of enthusiastic openness to peer collaborators from other countries are salient elements of thousands of interviews, written

reflections, and recorded collaborative activities – a data corpus in which there are zero references or mentions of antipathy or uneasiness at such collaboration. Distributed project-based learning, especially over time zones or national boundaries, requires many layers of orchestration, nuance, and logistical coordination. But getting kids to appreciate and enjoy and seek to understand peers who differ greatly from them appeared to be the easiest and most natural component of the process (Hamilton and Owens 2018).

Additionally, it appears that online collaborations between students, especially including videoconferencing, effectively primes for affectively positive and academically compelling in-person subsequent collaboration, a phenomenon that university researchers experience regularly in academic collaboration but that is not structured into K12 education. And the IC4 project has repeatedly observed the “helper’s high” phenomenon (van der Linden 2015; Lee et al. 2019) of increased sense of well-being and confidence by students who treat science and math as subjects to help others understand, rather than as subjects that they have to succeed in a test on. Such dynamics can characterize next-generation learning environments.

Assessment of Individuals and Teams in Complex Collaborative Environments

Information technology advances have enabled profoundly important innovations in learning and education. These in turn require reconceptualizing student and group assessment. Digitally mediated project-based learning environments that enlist or develop a range of interrelated competencies and that yield digital artifacts obligate processes that extend far beyond traditional academic assessments. The degree to which an individual can help size up her or his role in a group project, create new ways of looking at the project, or facilitate retrieving information or building knowledge all bear on cognition and learning. In the example of the IC4, student teams produce videos to teach or explain science and mathematics concepts or create presentation

remixes. These types of projects center on topics typically associated with academic disciplines. They are affected not only by prior knowledge in those disciplines but other factors such as expressive skill, representational creativity, self-efficacy, and ability to take the perspective of others.

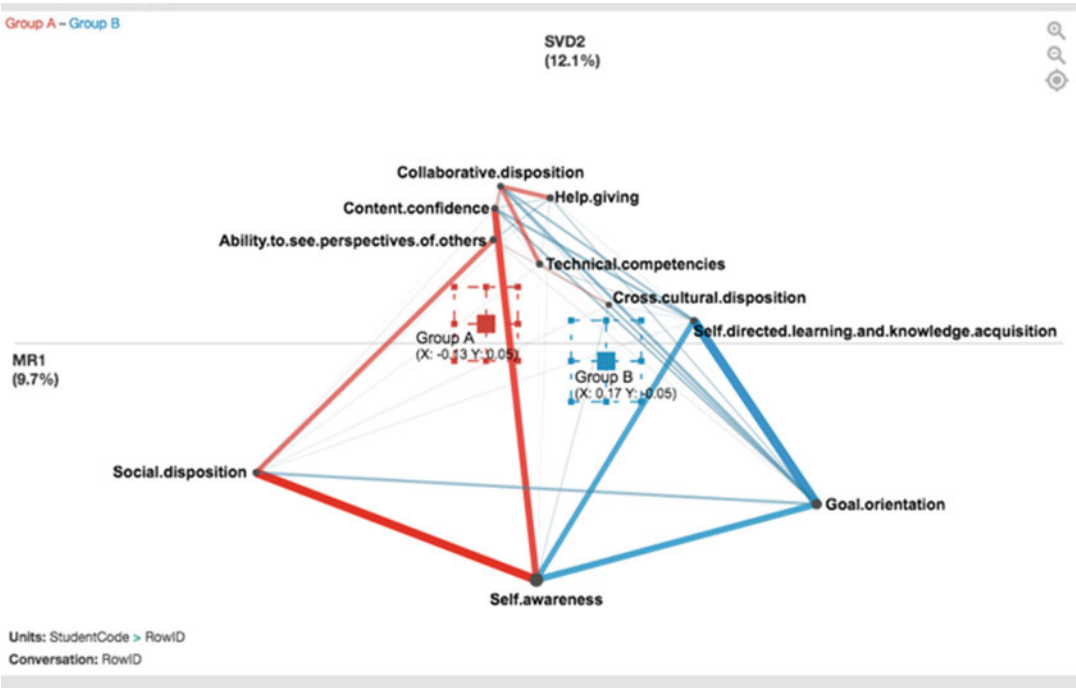
Connecting skills and dispositions from a complex setting such as those involved in distributed collaborations is beyond the capability of any pre-digital assessment system. IT-enabled learning analytics promises to have the transformative potential for assessment that IT has for learning.

One new analytics methodology called epistemic network analysis (ENA), developed by David Williamson Shaffer and his team at the University of Wisconsin in the USA, provides insight into how IT systems can help to reconceptualize what assessment systems can deliver. ENA is a quantitative ethnographic approach (Shaffer et al. 2009; Shaffer 2017) that originates in, but then extends beyond, the data visualization techniques of social network analysis. In social network analysis, individuals typically represent nodes on a graph, and connections between them are edges of the graph. Rather than using nodes to represent individuals on a graph, ENA can graph at the student level modeling a network of connections between elements of an individual’s epistemic frame. An epistemic frame can be considered a gestalt or ensemble of heterogeneous factors, such as complex reasoning skills, beliefs, social connections, or values that an individual can bring to any activity (such as collaborative problem solving). Each of these elements can be represented as a node on a graph, with the strength of association between any two elements of an epistemic frame differing from student to student or group to group.

From a collection of such networks (i.e., the networks of some set of individuals), ENA creates an ENA space. These networks can be viewed in the ENA space, individuals or groups can be compared, and differences between individuals or groups (e.g., between students in different countries) can be quantified. The process uses mathematics like principal components analysis or factor analysis. However, while factor analysis isolates a list of possible latent variables through

load factors based on subject responses, ENA identifies latent patterns of connections between epistemic frame elements by measuring temporal proximity – how often the elements appear near each other. Such ensembles (collections of heterogeneous factors) can also include data points captured in collaborations (such as conversational flows, pauses, affective valence indicators, or dialogic content sophistication). This permits visualization of trends in both individuals and groups. Data resulting from collaborative exchanges can be treated as input streams that then yield graphs or visualizations that highlight relationships in group or individual learning. For purposes of illustrating connections between factors, data cited in Lee et al. (2019) appears in Fig. 3. Based on a series of constructs identified in forerunner projects (Hamilton 2015; Hamilton et al. 2016), a series of codebook of constructs was developed. They were identified as important aspects of student experience in media-making

projects between peers in different countries and appear in Lee et al. (2019). Interviews with IC4 members in different groups revealed contrasts: mathematical centroids for codes attached to interview utterances in Group A and Group B are marked with a dotted rectangle and reflect different group dispositions. The first group’s emphasis on content confidence, ability to see the perspectives of others, and social disposition contrasted with the goal orientation and self-directed learning constructs that frequently came up in the second group. The construct most prominently shared by each group was self-awareness. This illustrates the potential value in the ability to visualize salient connections and epistemic commitments collaborators make in their projects. ENA can be considered as a philosophical marker for the type of learning analytics that will serve practices such as distributed project-based learning, because of its emphasis on treating data holistically. Analytics typically require forming a



Distributed Collaboration in Project-Based Learning and Its Assessment in Next-Generation Learning Environments, Fig. 3 Network graphs model discourse patterns between two student groups, identifying construct

connections. Centroids and their confidence levels furnish visual comparison of distinct discourse patterns between the groups

narrative based on integration of originally separate large data streams that are captured in disaggregated form into the data ecosystem. Future systems that support personalized learning may indeed successfully create actionable and data-driven narratives from such streams. (A comprehensive survey of the learning analytics software education market, however, shows repeated tendency in commercial products to focus exclusively on data capture with virtually no attempt at alignment with sound educational practice or theory (Sarmonpal, in submission)). The approach that we believe most promising for consideration in synthesis and design is one that captures data as it is connected to other aspects of an individual's epistemic frame. This distinctive paradigm essentially suggests the potential for connecting heterogeneous data points at the point of capture to make sense of the learning design.

Research Directions

The complex world the next generation will inhabit requires complex skills of collaboration and parallel-processed competencies that far exceed what contemporary schooling entails. It will require sufficient design sophistication in learning environments to help prepare students for occupations that neither yet exist nor have even been imagined. The paths to authentic academic success in next-generation learning environments should be wider, more plentiful, and more pervasively experienced than in current and past generations.

Ironically, and happily, the researchers and practitioners on our planning team, along with the broader literature, have uncovered a compelling truth mentioned earlier about the potential for astutely designed collaborative learning: it fosters rigorous academic success even – and especially – among those who otherwise might be considered middling or mediocre in academics.

Those emerging professional competencies also include design of projects and raise important design questions. Virtual collaboration in project-based learning differs substantially from local teamwork. What design principles optimize virtual projects, especially as new enablements in

areas such as artificial intelligence, virtual reality, and augmented reality become more readily available? Within the context of IT-mediated quantitative ethnographies, how do trust, self-efficacy, help-giving, complex reasoning, and ability to see the perspective of one's collaborators affect one another? To what degree are these variables malleable in ways that can mutually reinforce and optimize the other variables? To what degree can they encompass or integrate complex combinations of both global and so-called micro-competencies for next generation and mid-century learning, such as those promoted by UNESCO's advocacy for major paradigm shifts in curriculum and learning (Marope 2017)?

The digital makerspaces or virtual project-based learning scenarios this entry reviews involve intense and crucial IT enablement in each of the areas of communication between students, the type of artifacts that they produce, and the advanced learning analytics that can help visualize individual and group progress, as Fig. 3 depicts.

In addition to questions above about project design, one of the most significant questions for research in this domain appears earlier. Why is it, or how is it, that children appear to have such fluid or easy-going ability to function across demographic boundaries when their presence is virtual rather than physical? To what degree does virtual presence prime or scaffold high-trust and productive face-to-face collaboration? These questions are important not only educationally but sociologically. Is there a path by which education innovation can create new conditions not only for greater intellectual or academic success but also for different ways that individuals from diverse or different populations engage with one another?

These types of settings also obligate research questions about the shifting role of the teacher. The technical skills in organizing digitally mediated collaboration around projects are far afield of the teacher preparation that many current educational practitioners have experienced.

There are no panaceas in education, and the vast majority of the world's population lives in a condition of educational crisis (Jeevan and Townsend 2015; World Bank 2017). Yet it is

arguable that never has society been on the cusp of such quantum jumps in the improvement of educational experience. It turns out that technology has enabled this potential, but the potential itself turns on ways that individuals can relate to one another more powerfully in shared ventures in the pursuit of solving problems or new knowledge.

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DIY

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DIYLab Activity

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E

Early Childhood

- [Educators and Children Perceiving Affordances with Working Technologies in Early Childhood Settings](#)

Early Years Literacies

- [Digital Technologies and Literacy Contexts for Young Indigenous Children](#)

E-Assessment

- [Information Technology and Assessment](#)

eAttendance

- [Attendance Records, Educational Management](#)

E-Books Among Students, Advancements in Higher Education

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The History of e-Books

Books and the way they are read have not changed much over the past centuries, since the first known manuscript written in the thirteenth century called the *Dresden Codex*. Unsurprisingly, books began changing in form, access, and content just before entering the millennium in 2000. Since then, books have been transformed into electronic books or e-books, which provide fast, easy, and downloadable reading matter. Digesting written materials in this form can be more convenient and portable.

The e-book was born in 1971 when the idea to save space and digitize books took root, and a digital library called the Gutenberg Project was set up (Lebert 2009). In 1974, the Internet first went live through the Internet Protocol (IP) which was later referred to as Transmission Control Protocol or TCP/IP, introduced by Vinton Cerf and Bob Kahn. The discovery of connecting oriented links and datagram between hosts provided the platform needed for e-books to flourish. Research centers and universities were among the first to take a foothold in the new field of the Internet in the 1980s. After the Web was created by Tim Berners-Lee in 1990, after 3 years, the first browser Mosaic was created, and from 1994 onward, access through the Internet began to spread rapidly.

The first e-book was available in July 1971, as e-text #1 of Project Gutenberg, a visionary project launched by Michael Hart to create electronic versions of literary works and disseminate them worldwide. In August 1998, Hart wrote in an email interview, "We consider e-text to be a new medium, with no real relationship to paper, other than presenting the same material, but I don't see how paper can possibly compete once people each find their own comfortable way to e-texts, especially in schools" (Lebert 2009). Peter Schweitzer, inventor of the @folio project, the prototype of a reading device, wrote in an email interview: "The luck we all have is to live here and now this fantastic change. When I was born in 1963, computers didn't have much memory." He added, "...by the combined effect of the Moore Law and the ubiquity of networks, we will have instant access to works and knowledge. We won't be much interested any more on which device to store information. We will be interested in handy functions and beautiful objects" (Lebert 2009). In terms of taking book access further forward, in the sixteenth century, Gutenberg allowed anyone to have print books for a small cost, while in the twenty-first century, Project Gutenberg would allow anyone to have a digital library for free (Lebert 2009).

Whether the hard-copy book is in jeopardy or not is arguable, but the great challenge to conventional print books is obvious; the twin

developments of digital text and the Internet have brought about major and rapid advances in all areas of our lives. We are now accustomed to writing and producing documents electronically, communicating electronically, storing and retrieving information electronically, and, increasingly, accessing it anywhere on a wide range of devices. In this context, the humble print book can feel rather anachronous, and students will rightly expect at least basic electronic access to their course books in the same way that they can access almost everything else they need freely, immediately, and online. As students' demands change, a transition to the print book's successor, the e-book, therefore seems both essential and inevitable.

Through some clear examples, it is possible to see how e-books have been incorporated successfully into educational practice, enhancing the learning experience for students, particularly students with disabilities and for distance learners. Through success stories that reflect well on e-books, such as exciting partnerships with research institutes, the development and promotion of an e-book app, the creation of an open living book, and new collaborations with e-book publishers and vendors to provide access to e-textbooks to students, all these examples show us that such practices are reaching the level of maturity needed for widespread adoption.

In the twenty-first century, universities are at the forefront of embracing the opportunities brought about by new technologies as well as understanding and overcoming their limitations. University leaders and managers concern themselves with developments that align with institutions' strategic priorities, deliver competitive advantage, improve teaching and research performance, reduce costs, and enhance value for money. E-books have the potential to engage with all these strategic priorities. Following the successful integration of e-journals into the academic workflow, e-books promise universities to enhance students' educational experience, enrich research resources, and streamline services. They have greater potential to transform the reader experience than e-journals, and yet they have experienced a long and difficult birth, suffering

from digital rights management, integration, discoverability, and functionality challenges.

Definitions of E-Book

The E-book is generally defined as text that is available in an electronic format such as Microsoft Word documents, text document (.*txt*), Hypertext Markup Language document (.*HTML*), or Extensible Markup Language document (.*XML*) (Hawkins 2000; Ormes 2002; McKnight and Dearnley 2003; Vidana 2003). Some definitions combine both the electronic text and the electronic reader device that are required for an e-book to be read (De Abrew 2001; Lynch 2001; Goh 2002; Grant 2002). Other definitions relate the conversion from print to electronic aspects of e-books, as printed text converted into digital format, to be read on a computer screen (Saurie and Kaushik 2001; Desmarais 1994). Connaway (2003) defined an e-book as a publication that is characterized by an electronic format, utilizing Internet technology to make it easy to access and use. Rao (2003) defined an e-book as “text in digital form, or book converted into digital form, or digital reading material, or a book in a computer file format, or an electronic file of words and images displayed on a desktop, note book computer, or portable device, or formatted for display on dedicated e-book readers.”

E-book readers as we know them have been around for almost a decade now. In 2004, the Sony Librie was the first e-ink device to be released commercially, although it was only available in Japan. Amazon only followed in 2007 with the first-generation Kindle, which was only available in the United States. By 2018, there was a huge variety of e-book readers available, and the problem was choosing between them. E-book databases are making their way into libraries through popular providers such as netLibrary, Books 24 × 7, Questia and Ebrary (Mullin 2002; Connaway 2003).

E-Books in Education

More and more computers connected to the Internet were available in schools and at home in the

mid-1990s. Teachers began exploring new ways of teaching. Going from print book culture to digital culture was changing relationship to knowledge, and the ways both scholars and students were seeing teaching and learning. Print book culture provided stable information, whereas digital culture provided “moving” information. E-books have the potential to involve three key strategic priorities common to most universities: to heighten the student experience and academic outcomes within an increasingly competitive environment; to drive innovation in learning, teaching, and research; and to help to use space and human resources more effectively and efficiently (Fyfe 2014). Enhancing the student’s experience is clearly a key strategic driver for all universities, sharpened by ever increasing global competition for well-qualified students.

In this age of technology, students can embrace the technology instead of avoiding it. From classrooms to libraries, students and educators are increasingly opting to use e-books because of the many advantages they give, such as the convenience, weight riddance, saving trees, and bookmarking, highlighting, annotating, and search capabilities. Libraries, on the other hand, have increasingly turned to providing e-book services due to problems such as diminishing budget, limited shelving space, increasing cost of new building and resources, the rising cost of repair or replacement of books, growing demand from users for electronic resources, rising cost of inter-library loan services, and the demand to support distance or distributed learning needs (Ismail and Zainab 2005). E-books have satisfied users’ desires for immediacy and provided an easier and convenient access, especially for remote users (McCarty 2001; Snowhill 2001). E-book subscriptions have solved libraries’ recurrent problems of lost, or stolen, or damaged books (Ardito 2000; Connaway 2003). Furthermore, the provision of e-books does not require unpacking, processing, and shelving and eliminates the extra time previously required to handle and process them before they can be used (Grant 2002; Helfer 2000). Features for handling e-books are also becoming more user-friendly, making it fairly easy for readers to browse, navigate, able to

view graphics and videos or submit keywords, and undertake full-text searching within a book or a collection of books (Snowhill 2001; Grant 2002).

E-Books at Tertiary Level

Academic libraries have traditionally played an important role in providing access to and disseminating information across learning and research communities. That role has now been extended to facilitating access to electronic resources such as e-journals and e-books through innovative technologies. Although both publishers and libraries are unsure about the future for and the impact of e-books, there is increasing awareness that e-books demand further attention (Vassiliou and Rowley 2008). Studies show that librarians are only partially aware of students' perceptions about e-books and that there are conflicting priorities among students, faculty, and librarians (Soules 2009).

Folb et al. (2011) assessed the use and factors affecting use of e-books by all patron groups of the Health Sciences Library System. A total of 871 patrons completed the survey, with an approximate response rate of 18.5%. The results indicated that library e-books were used by 55.4% of respondents and that, in general, respondents preferred print for textbooks and manuals and electronic format for research protocols and reference books. In spite of little promotion, 65.5% were aware of the e-book collection.

E-book popularity has been growing steadily over the past 5 or 6 years (Ramaiah 2005). Charles Sturt University, a major provider of distance education, has taken up the challenge of moving away from the traditional print-based method to electronic delivery of instructional material (Messing 1995). The Open University (OU) in the United Kingdom has also moved to an electronic paradigm in adopting the e-book as one of their primary learning materials. In Malaysia, the Open University Malaysia (OUM) also followed the trend by providing a digital collection in addition to more than 8500 volumes of books in its main campus and learning centers nationwide. The OUM's digital library provides access to

more than 40,000 titles in e-books and 18,000 titles in e-journals, respectively. Other than OUM, Malaysia Multimedia University, the University of Malaya, and the Universiti Sains Malaysia are among the universities that provide e-book services in their campus libraries. The newly opened Kuala Lumpur Library has also purchased and subscribed to e-books, while other institutions such as the National Library provides e-book services, although not on a very large scale (Primalani 2004).

On the one hand, results from some studies suggest that involvement with computers, through the use of electronic content and other new technologies, can promote positive attitudes toward learning and higher achievement among learners (Espinosa and Chen 2001; McCreary et al. 2001). Studies also showed that computer-based learning tools lead to significant gains in learners' performance in reading, mathematics, computer knowledge, and grammar (Shields and Behram 2000). On the other hand, regardless of the vast amount of e-books available and the great potential of e-books in education, findings from Abdullah and Gibb (2006) revealed that the majority of their respondents (60%, 823 out of 1372) have never read an e-book. This result conforms to the findings by Chu (2003), Gunter (2005), Perry (2005), and Bennett and Landoni (2005). They found that most of their respondents had not read an e-book.

This interesting finding leads to the question of whether the phenomenon is the same in other countries. This article will explore a country case – the situation in Malaysia. Specifically, the question will ask whether students have yet to read an e-book. Within this context, a case study aimed to achieve the following objectives:

- (a) To determine the extent of e-book usage among Malaysian students.
- (b) To identify the impacts of e-books on the Malaysian students.

The Case in Malaysia

A survey was conducted with students from various educational institutions and levels as the target

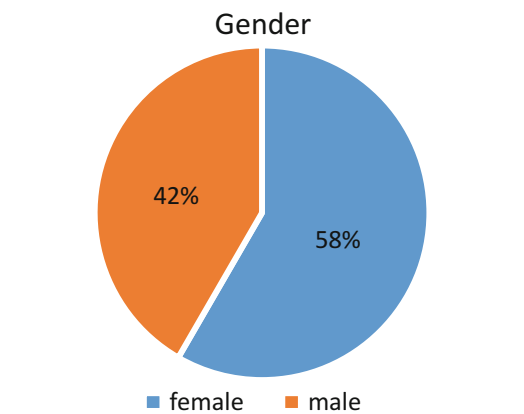
group using both field and online surveys. The field survey was held at the Universiti Teknologi PETRONAS, and the online survey was distributed to other university students from around Malaysia. Collectively, the survey obtained 666 complete responses. The respondents were given questions which addressed the usage of e-books, impacts of the e-book to them, and the limitations of the e-book. Besides the Universiti Teknologi PETRONAS, respondents came from a range of other educational institutions. Among them were the Universiti Malaya, Universiti Teknologi Melaka, Politeknik Sultan Azlan Shah, Universiti Kuala Lumpur, and a secondary school.

Demography of Respondents

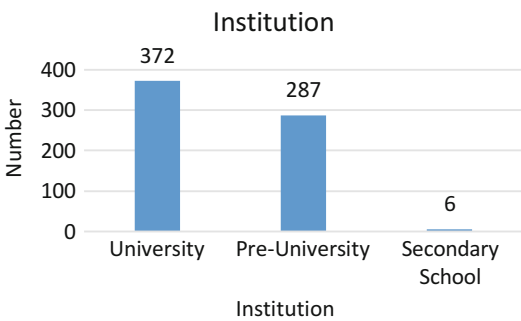
The majority of the respondents were female with 56%, while males were 46% (refer to Fig. 1).

Explicitly, 372 respondents were in the tertiary level, 287 were in the pre-tertiary level, and 6 were in secondary school (refer to Fig. 2). The highest number of respondents were in Engineering, Science and Technology (258) followed by Finance, Management and Commerce (96), Education (81), and one respondent was from Accounting (refer to Fig. 3).

A majority of the respondents (83%) reported that they were aware of the e-book before the survey was conducted, while only 18% of them were not (refer to Fig. 4).



E-Books Among Students, Advancements in Higher Education, Fig. 1 The respondents' gender



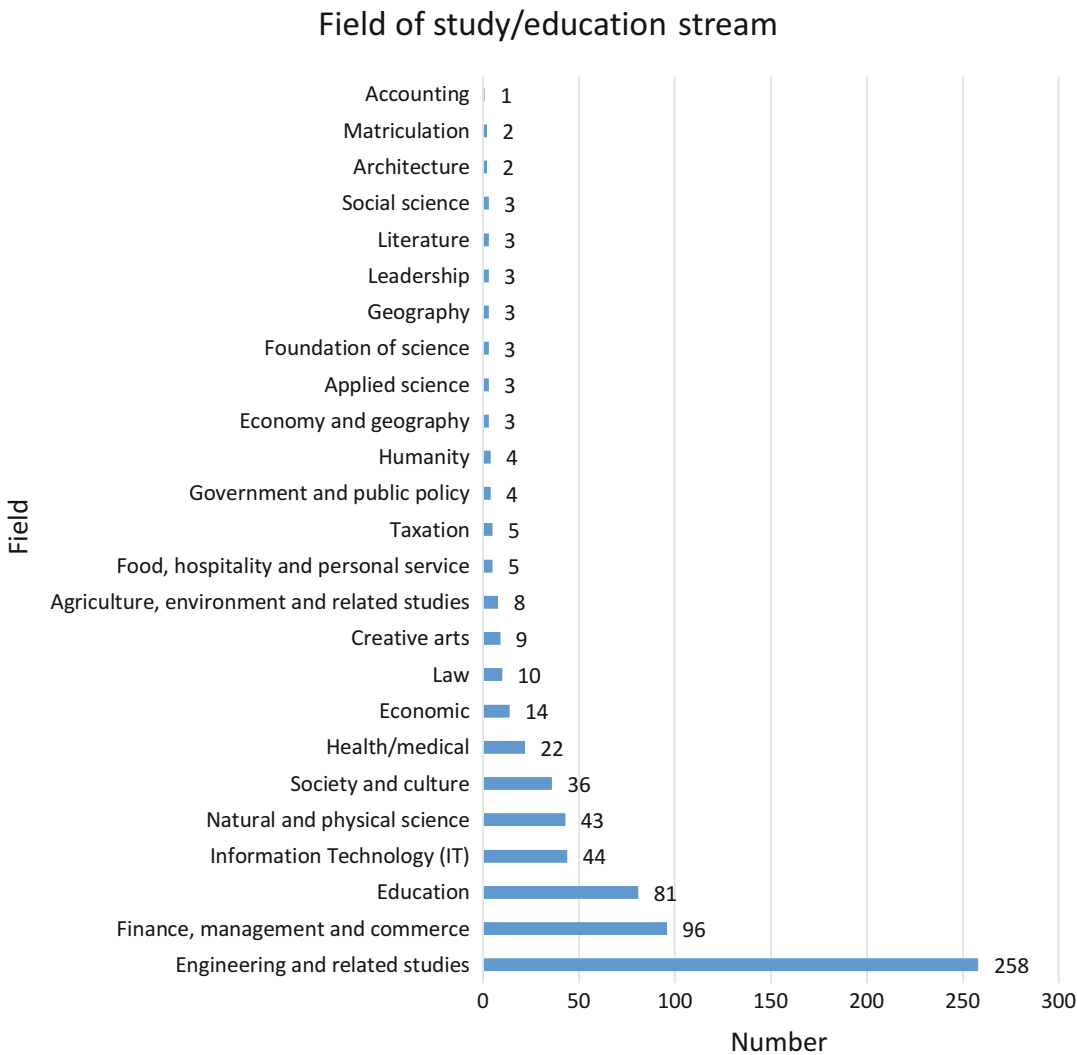
E-Books Among Students, Advancements in Higher Education, Fig. 2 The current institution of the respondents

Usage of e-Books

Figure 5 shows the frequency of e-book usage. The frequency of e-book usage in a month was reported at 35%, followed by 29% weekly and 14% daily. Surprisingly, 22% reported that they had never used an e-book before. The postulation that the e-book is not a popular tool used by Malaysian students could be concurred, since the results show that only about one third of the respondents use the e-book in a month. It is unexpected to find students who reported that they had never used the e-book, especially considering that all schools are equipped with computer laboratories.

Laptops (42%) are the most preferred access device, giving the respondents a better self-reported experience (refer to Fig. 6). Following closely are smartphones (33%), tablets (17%), and desktops (8%). Although the smartphone was the least preferred device to use for e-book utilization due to its display screen size which smaller than other devices (Kowalczyk 2017), the smartphone fared much better in this study than the desktop. Maybe sometimes size does not matter; some other factors may be affecting the respondents' preferences.

The respondents were asked about the location where they accessed e-books. A majority of the respondents use the e-book almost anywhere (32%) followed by both at school and at home (27%). When separated, those who used the e-book in school were reported at 24%, while at home it was 17% (refer to Fig. 7). As anticipated, since the preferred device is the laptop and the smartphone, the location of usage could be anywhere. But, for the 17% of the respondents who



E-Books Among Students, Advancements in Higher Education, Fig. 3 The respondents’ field of study/education stream

only use the e-book at home, this could be due to the device or limited connectivity.

When asked what the e-book is usually used for, 69% say it is for research purposes followed by searching for the latest information (17%) and entertainment (13%) (refer to Fig. 8).

When asked specifically as to why the e-books were used, 361 of the respondents said that they used the e-book to search for some topic using a keyword search on the net. Other than that, 159 respondents said they intentionally used an e-book because physical books are too expensive,

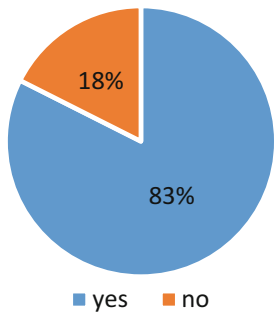
while 50 respondents said that the physical books were unavailable on the shelf. However, 85 respondents said that they used e-books to search for books which are only available in electronic form (refer to Fig. 9).

The respondents were asked how they read the e-book. Most of them read the e-book online (49%), while almost the same percentage downloaded the e-book and saved the book on their respective devices (48%) (refer to Fig. 10). Only 3% had the book printed on paper. It could be assumed that sufficient connectivity resulted in

Malaysian students using the e-books through online reading (at home or at school) or downloading them. Also, it could be assumed that the respondents utilized large capacity devices.

Availability wherever and whenever were the two most exclusive positive characteristics associated with uses of e-books. This statement was strongly agreed to, and agreed to, by 30% and 50%, respectively, of the respondents. Although a majority understood the capability of the e-book, 17% of them were unsure (refer to Fig. 11).

Before this survey, have you heard of e-books?



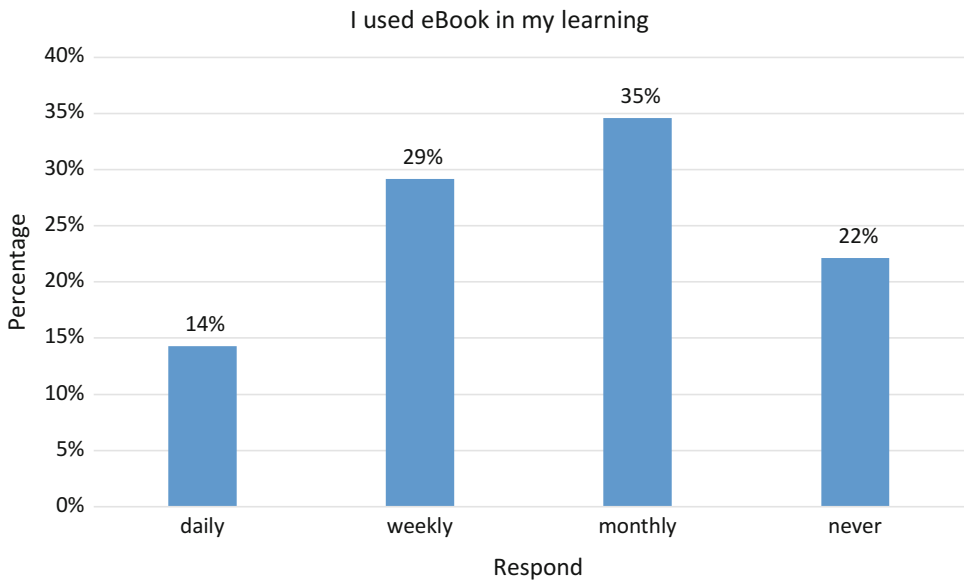
E-Books Among Students, Advancements in Higher Education, Fig. 4 The respondents’ acknowledgment of e-book prior the survey

Impact of e-Books on the Respondents

A majority of respondents were of the opinion that e-books were more practical and serve to better understand certain topics. As shown in Fig. 12, 58% of them agreed, and 13% of them strongly agreed. However, 23% of the respondents were unsure and 5% disagreed. This finding indicates that the e-book was received well by the students overall, and it can be a reliable source of information, especially when it comes to understanding subject matter.

As shown in Fig. 13, a majority of the respondents agreed (51%) and strongly agreed (23%) that after guidance given by their teacher, they were able to master their syllabus. This indicates that the e-book has a positive effect on the teaching and learning of an academic syllabus. It also indicates that a teacher’s role could offer an advantage for the respondents. However, it is also noted that 21% are undecided about the e-book’s effect.

In Fig. 14, 52% and 20% of the respondents agreed and strongly agreed, respectively, that they get fast and thorough feedback, response to or review of their performance in their learning process. However, 23% were unsure of the e-book’s capability, while 5% disagreed and 1% strongly

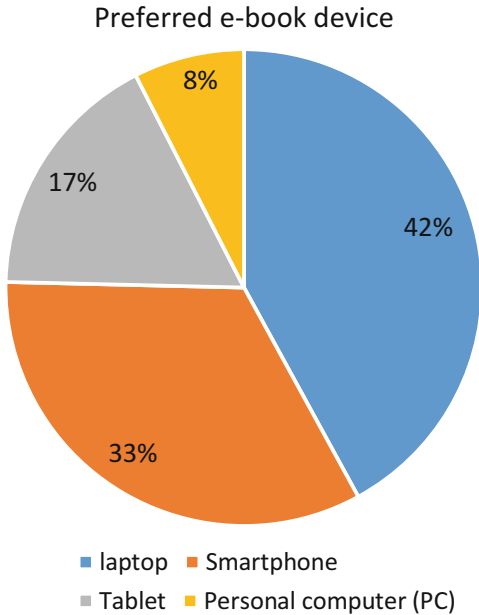


E-Books Among Students, Advancements in Higher Education, Fig. 5 Frequency of e-book usage

disagreed. This finding indicates that a majority of the respondents are familiar with the functions or features of the e-book, and students can use the e-book to monitor through self-assessments.

Figure 15 shows that a majority (41% agreed and 39% strongly agreed) of the respondents

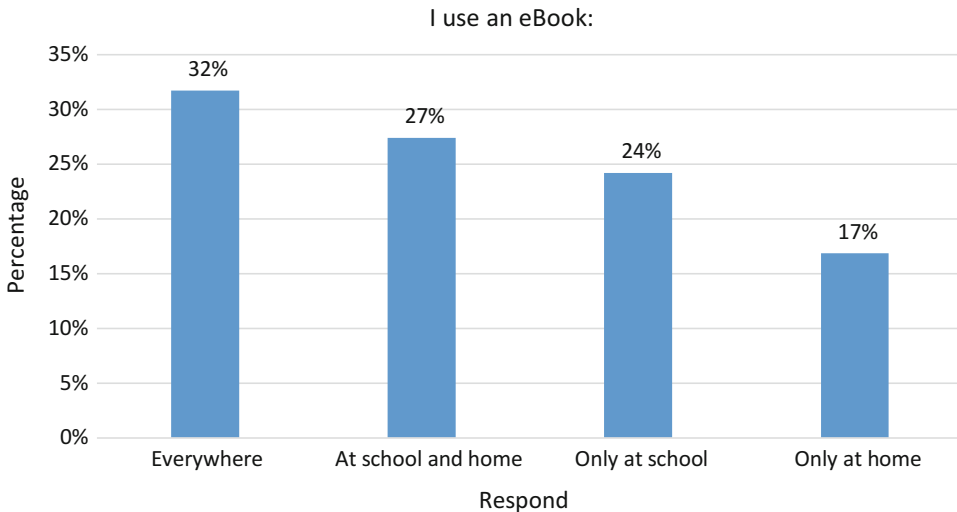
reported that e-books helped to lighten their schoolbag and also helped to maintain good body posture. A small percentage of 15% were unsure of this advantage, while a smaller percentage of 5% disagreed. This finding shows how using e-books in school could have positive effects on body posture of students using them.



E-Books Among Students, Advancements in Higher Education, Fig. 6 The preferred e-book device

The Limitations of the e-Book

As shown in Fig. 16, 176 respondents agreed that physical books provided them with reading pleasure rather than the e-books. A total of 171 of the respondents preferred physical books to the e-book because of hindrances such as low memory capacity, low battery life, and low screen resolution and color. A total of 144 respondents preferred physical books over the e-book because of Internet accessibility. This finding seems to challenge the opinion that Internet access at schools or universities in Malaysia is sufficient to support the usage of e-books. Overall, 121 of the respondents expressed that they preferred physical books rather than e-books because there is nowhere for them to jot down notes on the pages of e-books. Perhaps, what could be deduced here is the respondents are not exposed to e-book launchers that offer sidenote features such as those offered by Kindle (Purdy 2010).

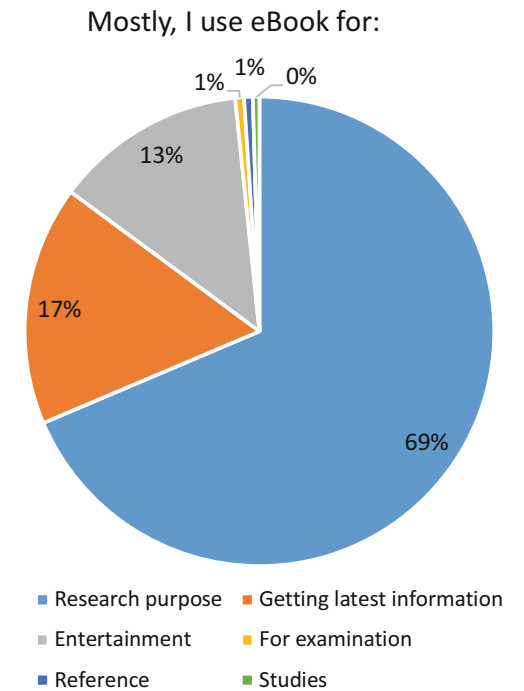


E-Books Among Students, Advancements in Higher Education, Fig. 7 The place that the respondent mostly use the e-book

A follow-up question required the respondents to answer a “yes” or “no” answer with an option to respond with “not sure.” As shown in Fig. 17, a

majority of the respondents (51%) were of the opinion that the device was the main hindrance of using the e-book, while 33% disagreed, and 17% were not sure. The implication of the response is that e-book devices still have room for improvement. This suggestion echoes Waller (2013). It was found that the reader device had limited battery life and therefore had to be charged; the device may also face technical problems and not offer access to the e-textbook platform.

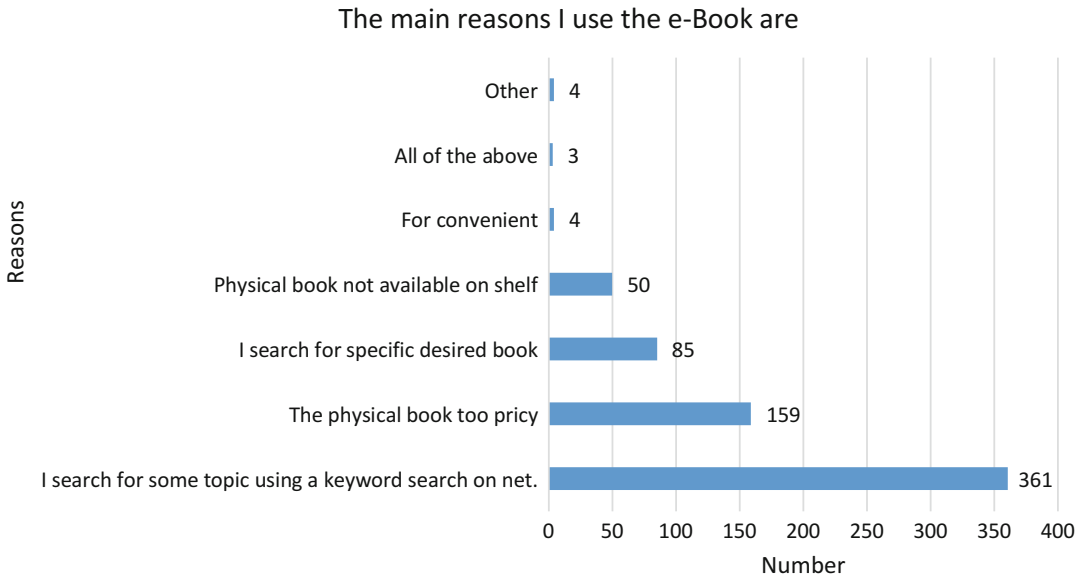
Finally, using the e-book requires some technical skills, especially when handling the e-book launcher device. As shown in Fig. 18, 38% and 12% of the respondents agreed and strongly agreed, respectively, that the lack of skills in handling the device and advanced features of the e-book encroaches the time they have set aside for reading. On the other hand, 18% and 5% of respondents disagreed and strongly disagreed with the above statement, while 28% of them were not sure.



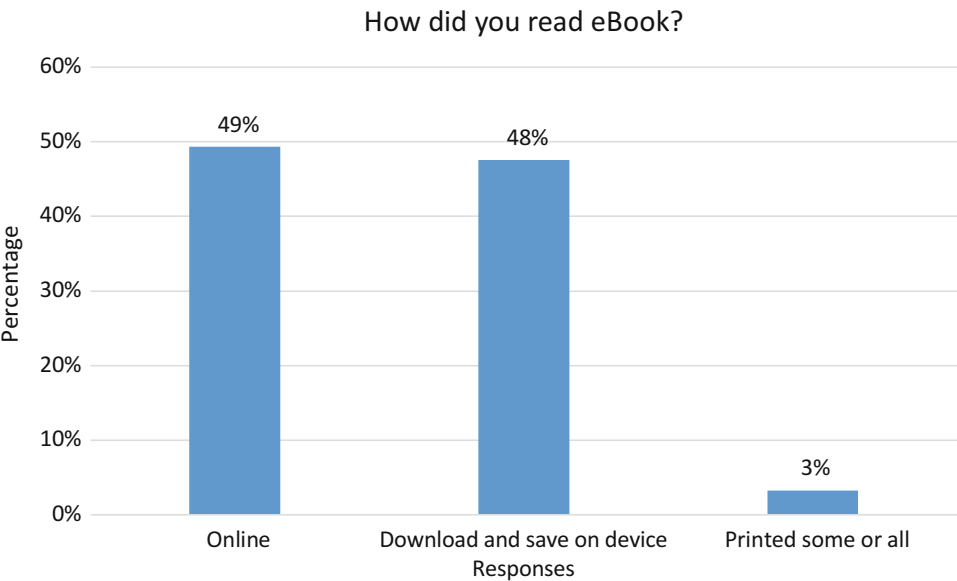
E-Books Among Students, Advancements in Higher Education, Fig. 8 What the e-book was used for

Strategies of Using e-Books in Classrooms

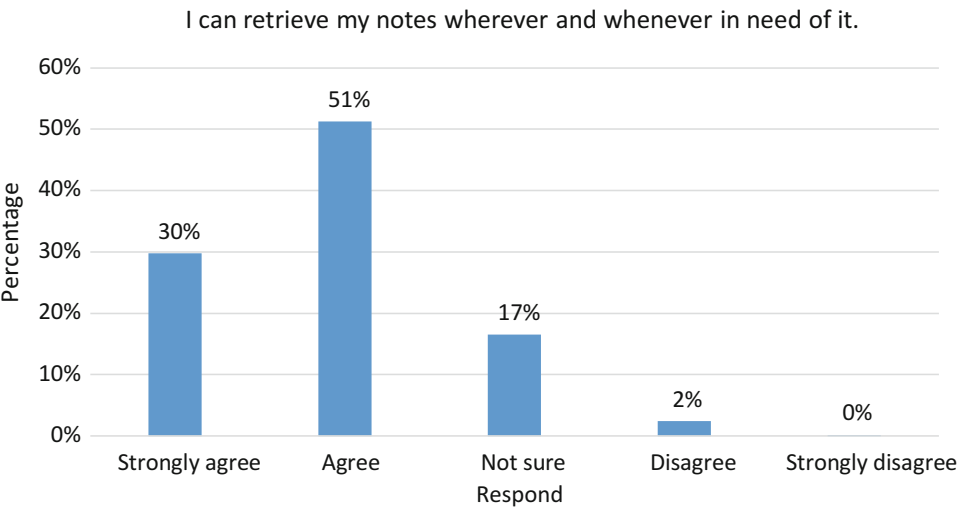
Drawing from the advantages and limitations of using e-books as textbooks, the following



E-Books Among Students, Advancements in Higher Education, Fig. 9 The main reason respondents use e-books



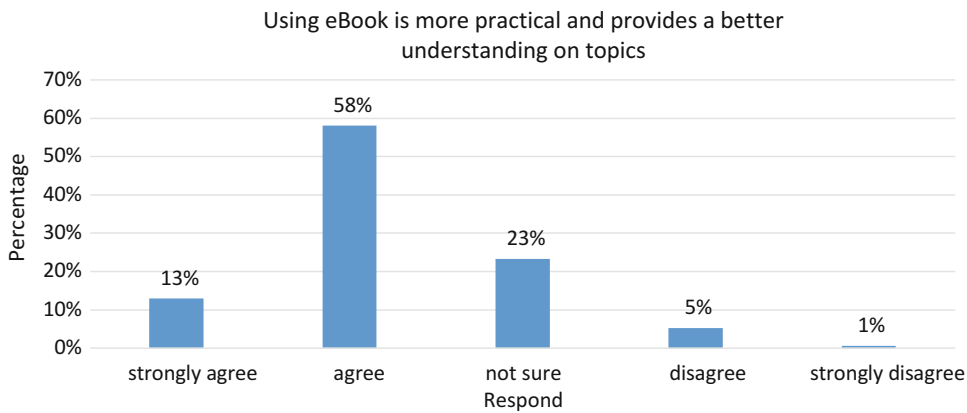
E-Books Among Students, Advancements in Higher Education, Fig. 10 The method of reading the e-book



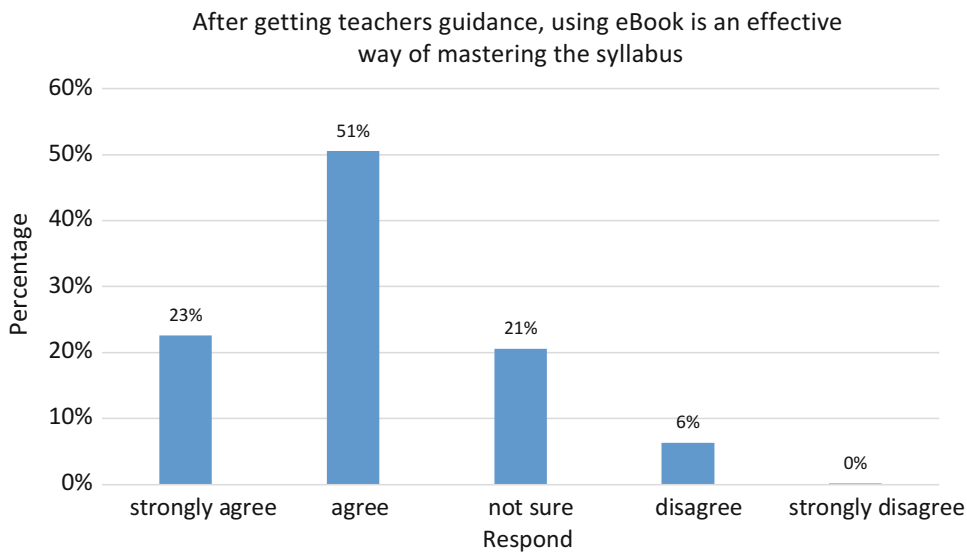
E-Books Among Students, Advancements in Higher Education, Fig. 11 The respondents opinion on the handiness of the eBook

questions may give brief pointers for lecturers or university administrators upon implementing the use of portable electronic e-book devices:

1. The use of e-books in the classroom involves a number of different personnel: lecturers, university administration, and technology specialists. Is there any collaboration among them to ameliorate content presentations of the syllabi with the e-book readers?
2. Technology is the most vital prerequisite in introducing e-books in class. Thus, it is essential to install specific software and hardware as a fundament in preparing higher institutions with the technology of e-books. So, are these technologies readily available? Do lecturers



E-Books Among Students, Advancements in Higher Education, Fig. 12 The Impact of e-book on helping user to get better understanding on the topics



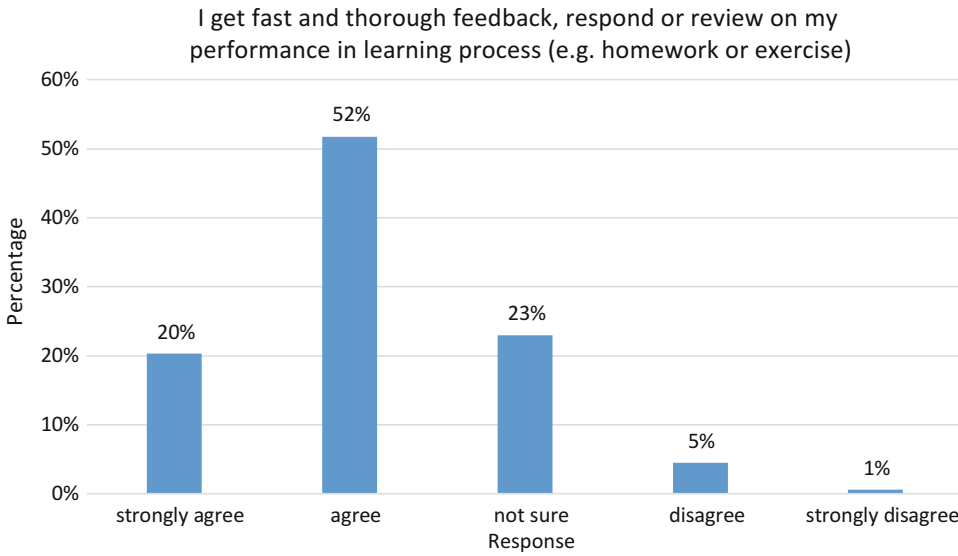
E-Books Among Students, Advancements in Higher Education, Fig. 13 The impact of the e-book as an effective method of mastering the syllabus after teacher guidance

- and tutors alike have knowledge and skills about e-books?
- How do colleges and universities provide instructions and manuals to pupils who are not IT savvy; are English for specific purpose pupils; or have special needs, such as autistic and Asperger syndrome? How can e-books support educators in helping these groups of students?
 - E-books may not have a long shelf life if not regularly and properly maintained. Is the maintenance of e-books properly planned for and

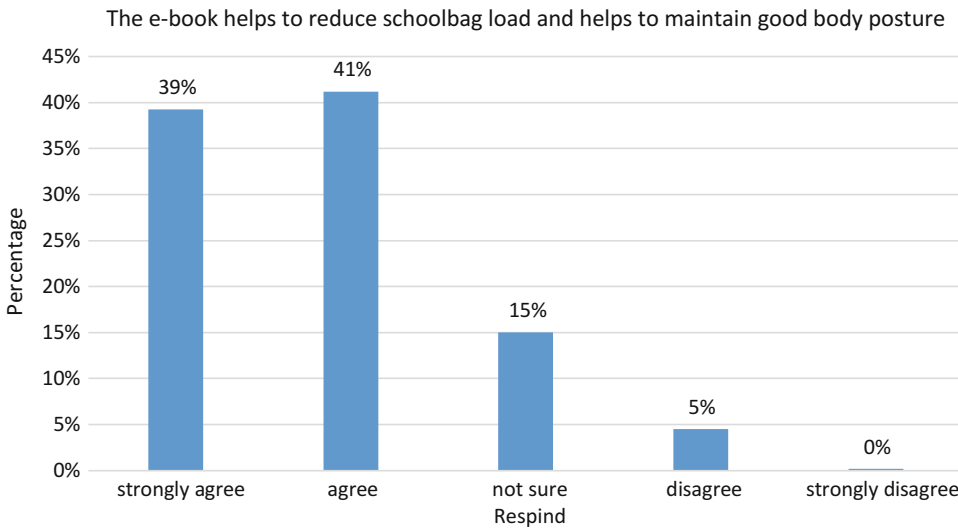
implemented? If they are, who is responsible for it? Will the service be readily available? Would it be affordable to the larger numbers if it were to be implemented more widely?

A Framework for Using e-Books as Textbooks

With the wide range of benefits that e-books bring to teaching and learning, e-books offer lecturers a teaching tool that can assist them in effectively



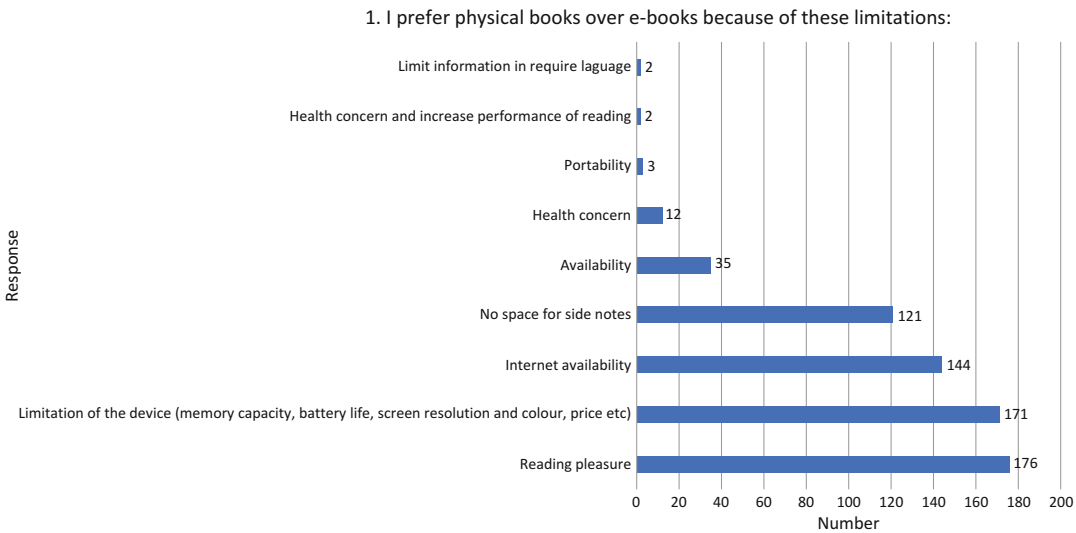
E-Books Among Students, Advancements in Higher Education, Fig. 14 The e-book gives fast and thorough feedback of learning performance



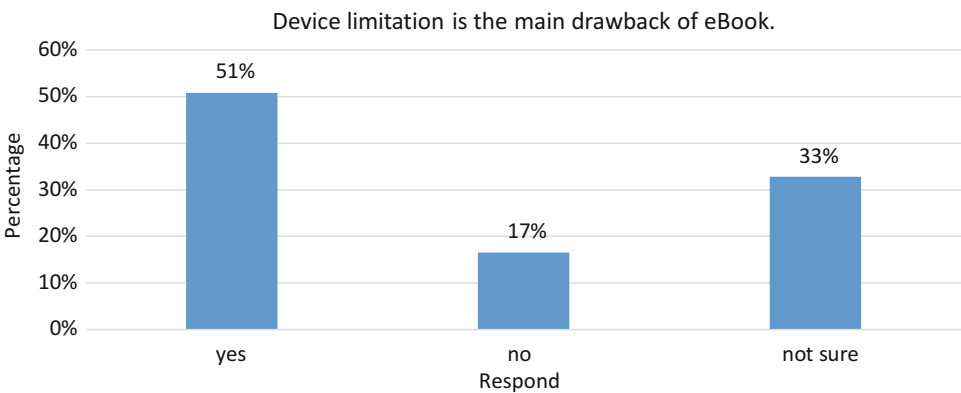
E-Books Among Students, Advancements in Higher Education, Fig. 15 The impact of e-book on users' health

conducting teaching and learning sessions in the classroom. Nevertheless, this article also acknowledges that e-books can never replace the fundamental function of lecturers, irrespective of the extent of e-book technological advancements. Furthermore, the effectiveness of the student's education depends on the types of feedback, direction, and encouragement that can only be provided by lecturers who

possess the knowledge and exude passion and enthusiasm. The use of e-books as textbooks is suited to today's modern learning environment; the education system has entered a new paradigm to keep pace with the needs of the emerging green environment. To provide a framework which can be utilized when using e-books as textbooks in the classroom, a framework of using technology within



E-Books Among Students, Advancements in Higher Education, Fig. 16 The limitation factors that made the respondents choose physical book over eBook



E-Books Among Students, Advancements in Higher Education, Fig. 17 The respondents’ opinion on the device limitation as the main drawback of e-book application

K-6 Programs in the National Reading Panel Report 2000 [10] can be considered. The framework consists of five general capabilities as detailed below.

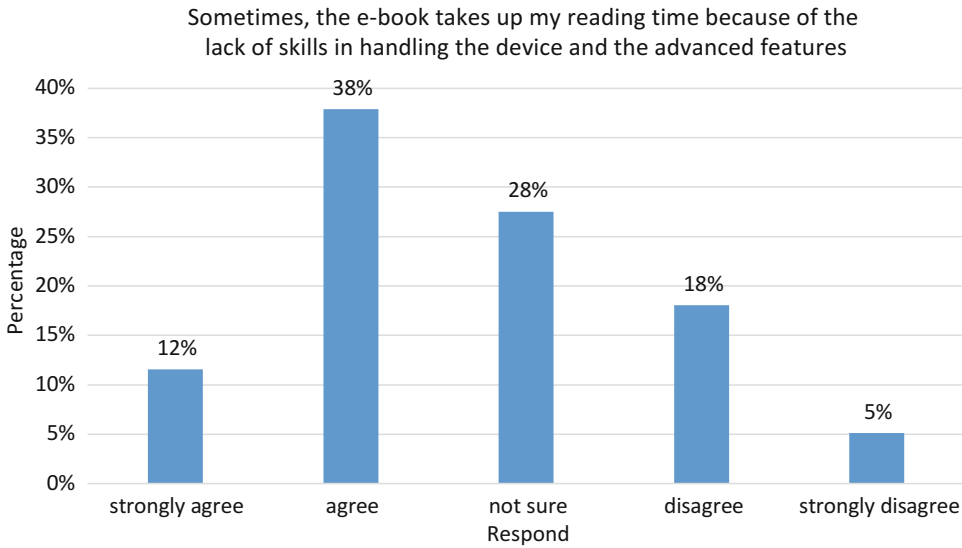
Presenting Various Presentations of Information and Activities

The extensive functions of e-books include many types of auditory or visual materials – including speech, text, music, animations, photographs, or videos – alone or in different combinations. Apart from that, e-books can link and combine different types of representations such as pictures with

sounds, oral readings with written text, videos with subtitles, or other combinations that could strengthen teaching and learning. They also provide enormous flexibility, allowing students to set the rate of speech, decide whether written text should also be read aloud, choose the language presented in text and speech, or decide whether to repeat the presentation.

Facilitating the Evaluations of Students’ Work

The capability of presenting information and activities in various formats also means that



E-Books Among Students, Advancements in Higher Education, Fig. 18 Handling skills and advance features of the device encroaches reading time

e-books can accept a variety of inputs from students, ranging from mouse clicks to written text as well as spoken words. It also consists of programs that permit students to check and mark their work, thus indirectly nurturing them to become independent learners. Since effective e-books are highly capable of recording and organizing information, as well as reporting that information in multiple formats, this function can be used to inform lecturers' instructional decisions and to make documenting students' progress much more efficient.

Automating Feedback for Students

Since e-books ease evaluation, they should also be interactive as well as able to portray user-friendly interfaces to ensure effective instruction. For example, when students respond to questions or read aloud, they need feedback to know whether they are correct; instruction to help them learn more; and opportunities to engage in additional work at appropriate levels to further their learning. When tasks require simple inputs, such as selecting from presented options or typing a word, e-books can be programmed to immediately evaluate each response and provide appropriate feedback with the addition of thorough explanation and description on particular answers.

Most importantly, aside from presenting a personal or individual progress report, e-books can be programmed to adjust the tasks presented, based on feedback from previous performances.

Providing Scaffolds for the Learning Process

Besides interactive instructions, it is vital for e-books to provide flexible support for the students' learning processes, especially in building vocabulary. Most e-book programs provide the ability to highlight text sections and take notes, and some even add the ability to create drawings within the book. All of these features can increase a student's comprehension of and attention to a given work. Some e-book programs have interactive dictionaries, providing just-in-time learning, that allow users to select any word within the e-books and get a definition instantly, have the definition read aloud, or request an instant translation to another language. This too serves as an attraction for a new modern definition of learning compared to the traditional chalk and talk method by lecturers in the past.

Ensuring Sustainable Resources of Knowledge

Providing scaffolds for the learning process should also be supported by fostering sustained

development of knowledge. E-books can contribute to this continuous effort through maximizing the availability of knowledge while reducing the numbers of trees cut down to produce printed books. Every year about 200,000 tons of paper are produced from four million trees for the publication of textbooks. This accounts for approximately 20% of the total paper used in the book publishing sector. Malaysia currently has 20 public universities, 24 polytechnics, 37 public community colleges, 33 private universities, 5 foreign university branch campuses, and about 500 private colleges. Besides that, various other educational institutions from the United Kingdom, the United States, Australia, Canada, France, Germany, and New Zealand offer twinning and franchised degree programs through partnerships with Malaysian colleges and universities (Ministry of Higher Education 2009). The number of trees cut down to produce textbooks to cater for all universities, and college students could easily amount to hundreds of thousands.

Recommendations and Conclusion

This entry has not only highlighted that the convention of e-books among university students is still not encouraging, but it has also exposed that it may seem that both students and lecturers would need more time to fully explore and take full advantage of using e-books in the classroom. Classroom administration is eased through the use of e-books and their application to manage the class and monitor individual students' activities and performance. Students' development can be closely and conveniently monitored, documented, categorized, and accessed. It is suggested that information technology (IT) support staff are required in each university to monitor all the e-books and to ensure the e-books function optimally. Similar to a desktop or laptop which requires periodical servicing, these e-books need an in-house technician since the users are new, are not accustomed to use e-books for education purposes, and are in a large number. The general opinion on the usage of the e-book among university students is that students will utilize the

e-books if their lecturers and the university provide a suitable e-book environment. Further research is suggested to determine the perceptions of the lecturers on the use of e-books in the classroom. The emergence of e-books as textbooks among university students requires all parties (i.e., lecturers, technologists, parents, and even policymakers) to deliberate on adopting and adapting themselves to the use of e-books. While e-books will not replace printed books in the near future, they will definitely be used to complement printed books. In classrooms, lecturers and students will start to value the convenience and accessibility of e-books. Technologists can expand e-book usage among a large number of university students by creating awareness on e-book usability. Parents will be exposed to the latest developments in education technology. Indeed, the introduction of e-books in education could be a jump-start in promoting a highly e-literate society. The suggested framework above may also suit a country's policy, but the development and publishing process of textbooks into e-books may be different from one country to another. The process may be subjected to policies made by the Ministry of Education of a specific country to possess the full copyright of publications.

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Education

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Educational Assessment

► Information Technology and Assessment

Educational Assessment, Educational Data Mining, and Learning Analytics

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Synonyms

Artificial intelligence in education; Big data in education; Educational data mining; Learning analytics; Learning dashboard; Teaching analytics

Definitions

Baker and Yacef (2009) define Educational Data Mining like a “discipline, concerned with developing methods for exploring the unique types of data that come from educational settings, and using those methods to better understand students, and the settings which they learn in.”

The definition of learning analytics prosed by Siemens (2011) is “the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs.” It could be useful to precise the level of the analysis; Buckingham Shum (Buckingham 2012) proposes macro-, meso-, and microlevels that refer to the range of the target. Macro-level targets cross-institutional analysis, meso-level is the institutional level, and microlevel is the individual level. Learning analytics use different computer, mathematics, and statistical method and technics according to the kind of analytics (descriptive, diagnostic, predictive, and prescriptive). The results of learning analytics are tools to assist human stakeholders

who constitute the learning system, like students or teachers.

Educational Data Mining and Learning Analytics Research Position

The theme of *Educational Data Mining* first appeared during the ITS (*Intelligent Tutoring Systems*) conference in Montreal in 2000 (Gauthier et al. 2000). But it is really in 2005, with the first workshop on EDM held in Pittsburgh in conjunction with the AAAI (*Association for the Advancement of Artificial Intelligence*) conference that the theme started to take off. Most of the research works presented at that time were led on data coming from ITS (Koedinger and Corbett 2006). The first state-of-the-art work was published in 2007 by Romero and Ventura (2007) and was followed by the creation of the yearly EDM conference in 2008 and of its associated journal, the *Journal of Educational Data Mining* (JEDM), in 2009. In parallel, and independently, the *Society for Learning Analytics Research* (SoLAR) was founded in 2011 with its associated yearly conference, LAK (*Learning Analytics and Knowledge*), followed in 2014 by its own journal, the *Journal of Learning Analytics* (JLA). Finally, the AIED community has been structured for three decades around two alternating biyearly conferences, AIED (*Artificial Intelligence in Education*), which became yearly in 2017, and ITS (*Intelligent Tutoring Systems*), as well as a journal, IJAIED (*International Journal of Artificial Intelligence in Education*).

Very early on, the two new communities (EDM and SoLAR) have acknowledged each other and the differences that exist between them, mainly in the background of its lead members (semantic web for LA, educational software for EDM), the analysis techniques they mostly use (social network analysis for LA, more machine learning for EDM), and their overall goal (empowering learners and teachers while leaving them in charge for LA, automated adaptation by the computer for EDM). Those key differences are well summarized in Siemens and Baker (2012). The principal difference between Educational Data Mining and

learning analytics is that results (algorithms, methods) are used directly by computer learning system in the case of EDM while the target of learning analytics still the humans: “EDM has a considerably greater focus on automated discovery, and LAK has a considerably greater focus on leveraging human judgment” (Siemens and Baker 2012).

Through an analysis of the social networks of the conference reviewers and journal authors from the AIED, EDM, and LA community, Labarthe et al. (2018) have shown that Siemens and Baker’s call has been heard, as more and more scientists are at the frontiers between the communities. The research themes however remain clearly distinct, as shown by the keyword analysis of the journal abstracts proposed by Labarthe et al. (2018), with an emphasis on automation and prediction for EDM and visualization for LA. However, these are the different pieces of the same puzzle: enhancing learning experience through technology. Predictive models, sequential patterns, analysis of social interactions and textual analysis coming from techniques in artificial intelligence are ongoing topics about Educational Data Mining, while dashboard and prescriptive analyses to assist human decisions are ongoing topics about Educational Data Mining.

Cross-References

- Artificial Intelligence in Education
- Assisting People with Autism Spectrum Disorder Through Technology
- Assisting People with Physical Disabilities Through Technology
- Assisting People with Vision Impairments Through Technology
- Assisting Students with Attention Deficit Disorder Through Technology
- Assisting Students with Intellectual Disability Through Technology
- Assisting Students with Learning Disabilities Through Technology
- Assistive Technology and Inclusion, Philosophical Foundation
- Assistive Technology and the Gifted Learner
- IT on Teaching and Learning Process of Visually Impaired Students
- Multimodal Learning Analytics
- Teacher–Student Relationship and Online Social Networks

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Educational Change

- Information Technology for Local Education Authorities and School Districts, Use of

Educational Communications Technology

- [Computers and Educational Improvement](#)

Educational Computing

- [Bunyip, The Australian Educational Computer that Was Never Built](#)

Educational Data Mining

- [Educational Assessment, Educational Data Mining, and Learning Analytics](#)

Educational Management Systems

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Educational Material

- [Institutional Repositories Versus Learning Object Repositories, Challenges and the Way Forward for Higher Educational Institutions](#)

Educational Programming Environments

- [Technology-Enhanced Learning in Programming Courses, Role of](#)

Educational Resources, Geographical Information, Geomedia, and Learning

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Definition

Learning with geomedia encompasses all forms of learning that use implicit or explicit geospatial referencing using a coordinate system across a wide variety of topics, subjects, pedagogical aims, and learning environments. Technically, this is nowadays mainly based on Geographical Information Systems (GIS) that allow to digitally collect, to store, to analyze, to visualize, and to communicate spatial data. The relevant GIS nowadays are ubiquitous and immersive, implemented in online services and cloud databases and often accessible through mobile handheld devices, e.g., smart phones and tablets.

Within the field of geoinformation/geomedia and learning, four major strands of thought can be identified that follow distinctly different pedagogical aims. These are a technical/industry argument fostering the development of a geospatial workforce, a Spatial Thinking argument that supports the development of Spatial Thinking skills along the paradigmatic settings of the spatial approach and therefore linked to science education, a Spatial Citizenship approach derived from critical cartography and participation and therefore the humanities, as well as a Spatially enabled Learning approach that uses geoinformation as system to support learning processes across subjects through almost complete spatial referencing of learning materials and outcomes as a spatially organized learning suite.

Introduction

The Technological Domain and the Geoinformation Society

Human action takes place in space, produces and reproduces space and place taking into account societal and physical rules, and appropriates space (Werlen 1993). As means of action, humans have been using geoinformation for centuries. A description of a specific place, explaining a route to someone else, using the sun and stars for orientation, using signposts or producing a sketch map to depict the supposed location of a treasure all contain geoinformation. This type of geoinformation usually consists of a location that is more or less exactly defined, as well as attribute data detailing specific qualities of the location, area, or route described. Thinking of a verbal description of the last holiday, people usually look into where it was, what the specific qualities of the place were, how they got there. Early rulers both in Asia and Europe kept track of their subjects in terms of spatialized data for tax collection and the reproduction of power structures using territorial strategies. All these actions clearly can be “put on the map” using their location.

Starting in the early to mid-twentieth century, additional technologies became available for mapping agendas. These include first aerial photography developed for the military in reconnaissance flights leading to a distanced view of the earth’s surface from above during World War I, which transformed the view of the world into an additional bird’s eye perspective. Later, with the advent of additional computing possibilities, GIS were developed for peaceful purposes in Canadian forestry, profiting from the possibility to map, store, and analyze data of large tracts of land. While the technology was quickly enhanced through computing power, algorithms, and storage capacity, these Geographical information Systems clearly were expert systems that needed considerable academic and technical education to be used. At the same time, data collection was clearly an agenda of the nation state and its administrative entities.

In the early 1990, first steps were taken in the direction of including lay users in GIS-routines

(Schoorman 2000; Elwood 2006) following considerable critique from social geographers and critical cartographers (Pickles 1995; Schoorman 2000). These first public participation GIS (PPGIS) allowed for the attachment of values and weights to specific layers of data in decision support systems. Here, however, the available data was still fixed, and the algorithms were probably beyond the comprehension of most lay participants.

During the first decade of the twenty-first century, several developments took place at the same time: the advent of usable and cheap Global Positioning Systems (GPS) and the end of disturbed GPS signals allowed for the development of lay mapping (variously dubbed neogeography, location-based media, or Volunteered Geographic Information (VGI, Goodchild 2007; Sui et al. 2013). At the same time, these GPS systems became standard in the now ubiquitous smart phones. Mapping was no longer in the hands of administrative entities but was increasingly organized by private companies like Google and ESRI or open-source based as in Open Street Map. The current landscape may be termed Geoinformation society and can be described through the availability of the following features (Strobl 2014; Harvey 2013; Thielmann et al. 2012):

- Universal positioning through various Global Navigation Satellite Systems such as GPS and a wide variety of receivers on humans and moving objects
- Personal sensors as a tool to integrate data via location and personal preferences
- Location-enabled apps that allow place-specific personalization of information
- Augmented reality that provides a additional visual information through a variety of devices
- A change of the traditional bird’s eye cartography towards individualized visualizations of space
- New interfaces that change human–computer interaction from keyboard/mouse interaction towards touch and gesture driven forms of interaction
- Personal and interpersonal devices linked to cloud services

This newer development can be categorized in three phases (Wilken 2018). In a first generation, these services needed an active registration of the users location (such as in the original Foursquare app). The second generation, then, involved passive location disclosure that automatically tracked the users' movements and linked this tracking to other content. Current applications, in a third phase now integrate location in all aspects of the business model, both in the interface as well as all algorithms, database population, and monetizing, as is the case with Uber (Wilken 2018, 26). This phase may be termed ubiquitous data capture. Location is the main integrator of all app processes here, and while it is becoming ubiquitous, the algorithms become increasingly opaque to the end user.

These – and probably more – developments over the coming years lead to new forms of communication, of the appropriation of space in both scientific and everyday settings, and consequently, to new forms and needs of learning.

Roles in Geomedia-Based Learning

Teaching and learning resources both theoretically and practically follow their availability as well as pedagogical thoughts. However, between these different ideas, specific differences can be detected in terms of aims, stakeholders supporting these approaches, and learning paradigms used (Gryl et al. 2014). Here, these approaches will be discussed under their title of (a) a technical perspective, (b) the perspective of Spatial Thinking, (c) the perspective of Spatial Citizenship, and (d) the perspective of Spatially Enabled Learning.

Depending on the technology and pedagogical approach, a variety of roles can be identified that link technology, GI professionals, and learners. Different from earlier thought, an increasing use of geoinformation in everyday communication leads to a widened classification of users in the professional GI domain. Consequently, these professional roles are (Fig. 1):

- Spatial information systems managers, who take care of the basic information-technology in terms of databases, technical ontologies, user interfaces, and other technical routines

- Spatial analysts who actively use the system from a scientific domain perspective, mainly producing analyses based on location, i.e., these are usually overlay, network and other algorithms developed in the spatial approach
- Spatial communication system managers who organizes mainly spatial visualization and communication tasks based on geoinformation
- And, in the case of education, didactical designers who have significant technological and pedagogical content knowledge (TPCK) to organize learning processes using geomedia

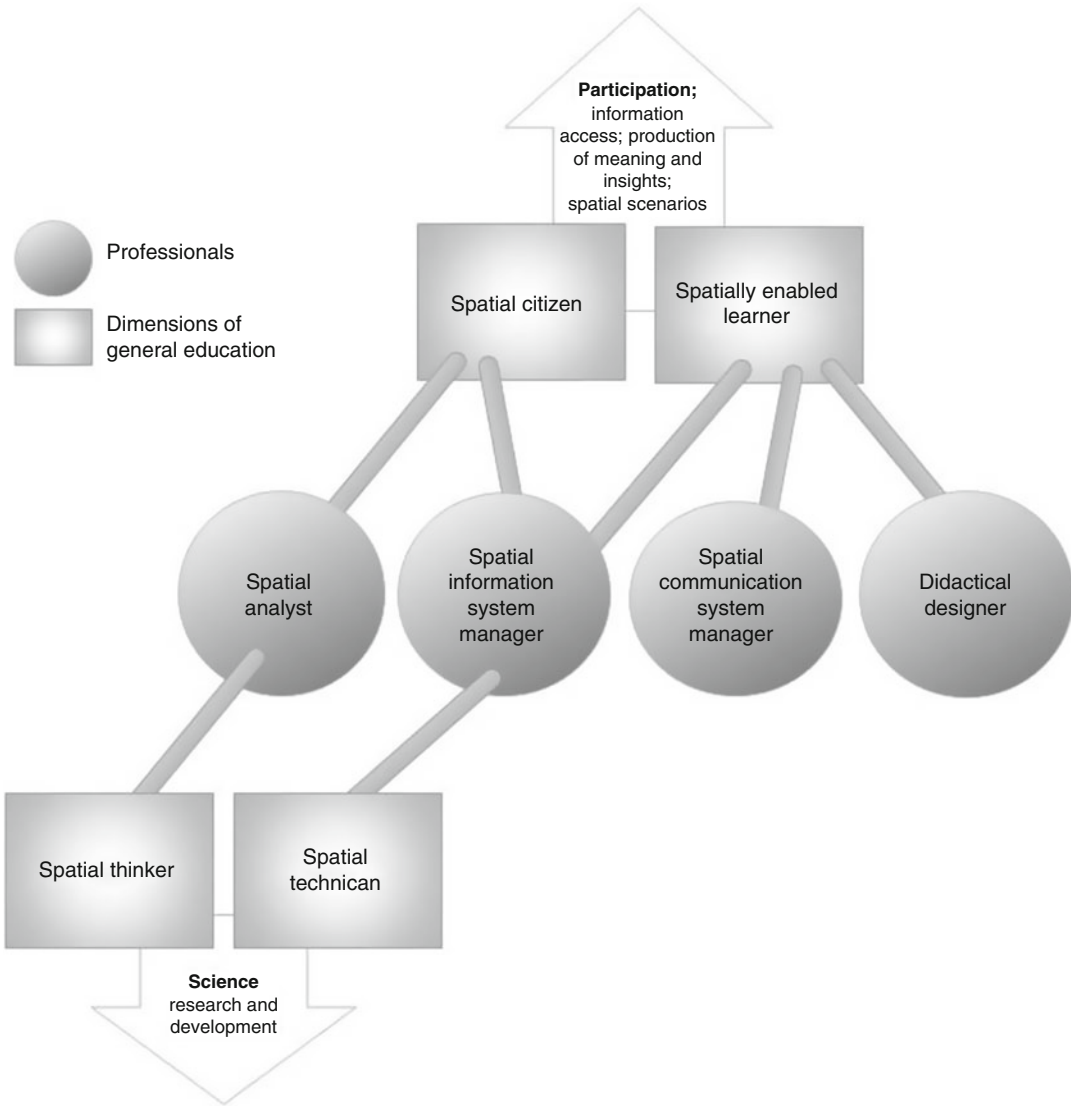
All these roles require significant education and training that cannot be acquired in secondary education and are therefore reserved as a aim of postsecondary education where a wide variety of respective courses is offered and theoretically founded in documents such as the GIS & T body of knowledge (diBiase et al. 2006; Wallentin et al. 2015).

Pedagogical Approaches in Geomedia-Based Learning

On the level of everyday users of geomedia, and therefore secondary school students as well, a very different set of roles is envisaged. These roles include a low level technician, a spatial thinker, a spatial citizen, and a spatially enabled learner (Gryl et al. 2014). This section follows the pedagogical arguments and gives information on exemplary topics and learning environments.

Technician: Enlarging the Geospatial Workforce

Actually, the technical argument and the argument of the enlargement of the technical workforce has been one of the first ideas that have inspired pedagogical engagement with geoinformation and Geographical Information Systems. This clearly is linked to a perceived bad image of the subject of geography in general education on part of geography educators, as well as early industry initiatives by software companies that for both economic as well as idealistic reasons wanted to make geoinformation, cartography, and spatial



Educational Resources, Geographical Information, Geomedia, and Learning, Fig. 1 Professional and general education roles in geomedia-based learning. (Based on Gryl and Jekel (2012), revised)

analysis available to secondary students (e.g., ESRI, Kerski 2003). Digital Geoinformation was seen as a tool to make the school subject more popular and in second line to provide the growing geospatial industry with a workforce of skilled workers.

Considering the state of the technology in the early 1990s, lots of energy in the classroom was spent on what today would be considered software training, providing software skills that

had a very short expiry dates as well as little conceptual foundation. In more general terms, it is rather questionable if general education should embark on software training at all. At the same time, the development of digital globes and later, the simplification of software and online application on handheld devices was much closer to the real-world experience of users who do no longer have to understand expert systems and full professional strength

software. Quite early, it was therefore noted that there was a need for “minimal GIS” (Marsh et al. 2007) in order to foster conceptual understanding instead of technical skills. Today, the discussion and praxis of GIS in a software training environment in secondary schools has widely subsided.

Spatial Thinker: Geomedia in Science Education

Spatial Thinking is neither new nor is it specific to the discipline of geography. Whenever organizing ourselves in space, humans do employ Spatial Thinking of one way or the other (Sinton et al. 2013). Quite a few disciplines are involved in secondary education when it comes to Spatial Thinking: maths, when looking into vector algebra; physics, e.g., concerning mechanics; geometry; and biology in a variety of scales from the double helix of the DNA to ecology (NRC 2006). It is this multiperspective view onto Spatial Thinking that allows the NRC (2006) to call for Spatial Thinking as a cross-cutting field of qualifications that should be widely implemented in secondary education:

Spatial Thinking must be recognized as a fundamental part of K-12 education and as an integrator and a facilitator for problem solving across the curriculum. [...] Our goal must be to foster a generation of students (1) who have the habit of mind of thinking spatially, (2) who can practice Spatial Thinking in an informed way, and (3) who adopt a critical stance to Spatial Thinking.

Basic Concepts

While the idea of Spatial Thinking in geography education was still originally inspired by the urge to bring GIS into the secondary education classroom, Spatial Thinking clearly was the first concept to do so with a general education background, and a wide array of geographers, psychologists, and learning theorists involved. It therefore pays dividends to take a closer look into the basic concepts employed and get these concepts related to their strengths and weaknesses.

The key to Spatial Thinking is a constructive amalgam of three elements: *concepts of space, tools of representation, and processes of reasoning*. It is the concept of space that makes Spatial Thinking a distinctive form of thinking. (NRC 2006, 12)

By *concepts of space*, authors of the Spatial Thinking approach mean various measures and dimensions within an absolute concept of space. These include, but are not limited to, relationships between units of measurement (meters, miles), different ways of calculating distance (for example, meters, time, travel costs), the dimensionality of spaces (two- vs. three-dimensional space), and the knowledge of coordinate systems. As linked to absolute space, these aspects may be mathematically calculated.

Concerning the term of *representation*, what the authors really mean is cartographical representation. This becomes clear through their dimensions of representation, namely the relationship between views (plan vs. three-dimensional visualizations, effects of projections, and principles of (carto-) graphic design (legibility and visual contrast). Again, all these forms of representation are geared towards a formalized representation of space within the rules of both traditional and modern (online-) cartography.

The notion of *spatial reasoning* is linked to analysis through spatial dimensions (distance, direction, and inclination). Reasoning here describes the extrapolation or interpolation of phenomena, the projection of (real or assumed) functional relationships describe through the dimensions of absolute space.

The spatial thinker therefore paradigmatically can be linked to the idea of the spatial approach, assuming that both natural phenomena as well as social phenomena can be described through spatial analysis. It therefore is a very useful approach for all phenomena that can be described as rule based, mainly in the sciences domain.

Exemplary Learning Environments

Water runoff and flooding. One of the areas that definitely may be explored using the Spatial Thinking approach are the relationships between morphology, precipitation, water runoff, and flooding. At the Z_GIS ideas lab, a learning environment has been built that consists (a) of a sand-pit for students to model their morphology, (b) a camera that allows for real time 3D-modelling of this morphology, and (c) the possibility to model precipitation and water runoff according to the

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Fig. 2 Morphology, 3D-models, and runoff modelling. iDEAS-Lab, Salzburg, foto by C. Gruber



morphology. Questions that have been successfully explored with students include the velocity of water runoff in regulated versus meandering rivers. Students then could explain the correlation between the lower inclination of the meandering river and a slower runoff (Fig. 2).

Another topic that can be used as a typical Spatial Thinking exercise is the *modelling of noise pollution* as has been demonstrated by various authors (Staub 2014; Bette et al. 2014). Measurements can now be taken with smart phone apps and distance-decay models derived from students' measurements – including anomalies of the model according to surface, vegetation, and other determinants of the spread of noise. The learning environment therefore also allows for a critical reflection of model building and accuracy.

A third application of Spatial Thinking may be the *development of hypotheses* and the reasoning from spatial visualizations. This has been supported by the development of rather simple online platforms like Gapminder. These platforms allow learners to manipulate and visualize data and draw their conclusions, e.g., build hypotheses of correlations similar to visual analytics. Quite a few teaching materials have been developed for this endeavor (see Gapminder s.a, Jekel 2014). Recent empirical research (Jekel and Lehner

2017) has shown that these tools actually pre-structure hypothesis generation, and that some of the representation aspects of Spatial Thinking are especially noteworthy for the development of learning environments.

Reception and Critique

The learning to think spatially approach (NRC 2006) leant itself towards the popularization of geomedia in education in a variety of ways. It first underpinned a technology-oriented approach by a wider pedagogical aim that was rooted in science education (MaKinster et al. 2014). It was thus still keeping the industry interested, as in most early applications a broad range of technologies was involved. In addition, the Spatial Thinking approach also appealed to moderate constructivist pedagogies and problem-based learning, and therefore, empirical research (Lee and Bednarz 2009). The approach was used in a wide variety of learning environments, and it reintroduced the paradigm of the spatial approach in secondary education. As such, it found its way in many legal documents of secondary education such as the US National Geography Standards (National Council for Geographic Education 2012).

While the general idea of learning to think spatially was brilliant in providing a further

strengthening of science education in the subject of geography and beyond by explicating a specific way of thinking relevant across science disciplines, the same cannot be said for the humanities. As Gryl and Jekel (2012) argue based on Werlen (1993) and Lefbvre (1993), the spatial approach as underpinning the concept has little relevance in the humanities as everyday human decision-making is usually not based on data, spatial laws, and rational choice. The same is true for the analysis of the political arena, where power, resources, persuasion, beliefs, and communication are important dimensions of analysis. In other words, learning to think spatially may be used with great benefits in the sciences domain; it should, however, not be transferred to the humanities considering the specific ontologies of society and space.

Education for Spatial Citizenship: Geomedia in Humanities Education

Education for Spatial Citizenship starts its pedagogical endeavor from a completely different angle. It argues that geomedia – as has been discussed in the introduction – has become an ubiquitous and pervasive resource that changes our everyday appropriation of space. It therefore is about learning how to navigate the world in respect to the physical world, in respect to the meanings attached to physical objects and environments and in respect the power relations involved in the production of meanings of space.

Basic Concepts

As all three of these dimensions are inherently linked with geomedia in this day and age, general education therefore should take into account the competences needed in regard to these conditions of the appropriation of space. In their programmatic paper, Gryl and Jekel (2012) argue for three dimensions that should be characteristic of a spatial citizen:

- An (increasingly minor) set of technical skills that allows citizens to produce, interpret, and prosume geomedia. This includes orientation in physical space using geomedia, simple tasks of mapping and lay map generation, and an

understanding of commenting on other peoples' spatial representations via online geomedia environments.

- The ability to both reflect others' use of geomedia, as well as be reflexive regarding one's own use of applications that are based on geomedia; this includes being capable of deconstructing maps and spatial representations used in political decision-making, as well as reflexivity towards surveillance and control of the individual built into spatially aware applications.
- The ability to communicate and successfully participate in society using geomedia, using the power of maps to good effect within the borders of human and constitutional rights. This dimension supports an activist approach to education, with the idea to actively change societal relations to follow either individual or collective interests.

This general idea of Spatial Citizenship is therefore rooted in critical thought, and more specifically critical cartography/critical GIS (Harley 1989; Wood 1992; Schuurmann 2000). It is clearly denoting the social construction of maps and the power relations involved. However, Spatial Citizenship then goes on to make the power of maps available to secondary students. The focus is both on the analysis of societal relations as well as changing exactly these relations using geomedia.

Exemplary Learning Environments

Mapping migration histories: The aim of mapping migration histories with secondary students in Seattle (Elwood and Mitchell 2013; Gordon et al. 2016) was to raise awareness of “hidden places of history,” places that were missing in dominant discourses of local history. The students' mapping exercise therefore have been examples of counter mapping – a form of mapping that actively places maps at the center of an alternative discourse. While these mappings were not considered to be powerful maps in themselves, they empowered students from migration backgrounds to find places of remembrance of their own family's histories; they were able to reflect on the power relations that lead to the

inclusion or exclusion of specific histories; and they were able to competently argue with city officials on new places of remembrance in the city's official history. Consequently, Gordon et al. (2016) do not speak of the power of maps that helps students to support their own ideas but discuss the mapping process as an activity that supports the formation of the political subject.

Reflecting on spatial privacy and surveillance: The ubiquitous use of geomedia also allows for a new quality of surveillance and control of both goods and individuals. Tracking of persons, linked surveillance cameras, and geo-located uttering on social media lead to the fact that everyday geomedia users not only produce volunteered geoinformation but also un-volunteered geoinformation. Google street view and high resolution imagery are other intrusions into spatial privacy (Armstrong and Ruggles 2005). Early conceptions on tracking and privacy for secondary education have been provided by Stark (2014) and Hofmann et al. (2013) who both looked into the tracking possibilities provided by geomedia. Stark emphasized the two-pronged nature of spatial surveillance, helping pupils to understand the benefits (for example, for city planning or in case of alpine accidents) as well as the possibility to intrude others' private spheres. Most of these exercises nowadays are easily done with students private smart phones which at the same time are the major contributor to surveillance close to no-one really wants to miss out on.

Confronting the extreme right through geomedia use in education: With the emergence of a distinct turn to the right in western politics, digital maps came used by various groups came into an educational focus. Maps here were used to change public opinion, and in several cases, transport explicitly nationalist and inhumane content. Pokraka et al. (2016) first provided a model to deconstruct these maps with secondary school students, and Golser and Jekel (2017) provided a model based on current definitions of rightwing extremism to analyze these maps providing teachers and students with the relevant categories (Fig. 3).

Another approach was suggested by Jekel et al. (2017) through mapping the physical symbols of NeoNazi movements in physical space of the city

under an initiative termed *#notmysymbol*. Mapping was organized through a combination of geolocated images of these symbols and the hashtag of *#notmysymbol* on Instagram. The initiative followed several aims, online mapping usable by stakeholders of the state, and law being the superficial starting point. Students were also asked to reflect on their mapping and interpretation practices as well as transfer the analytical capabilities developed to everyday media.

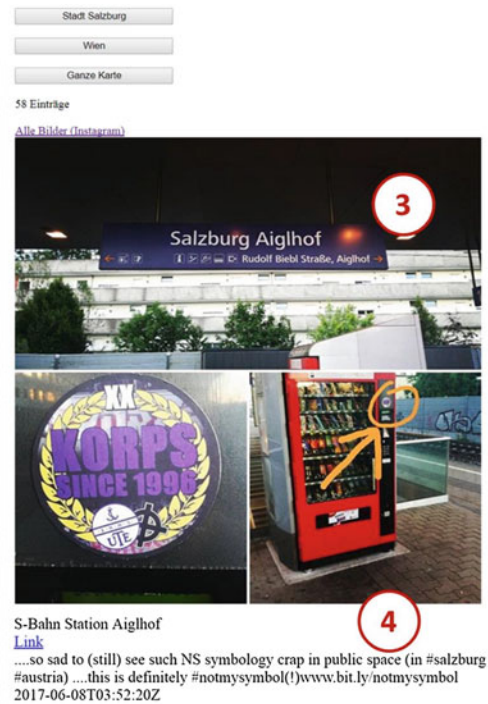
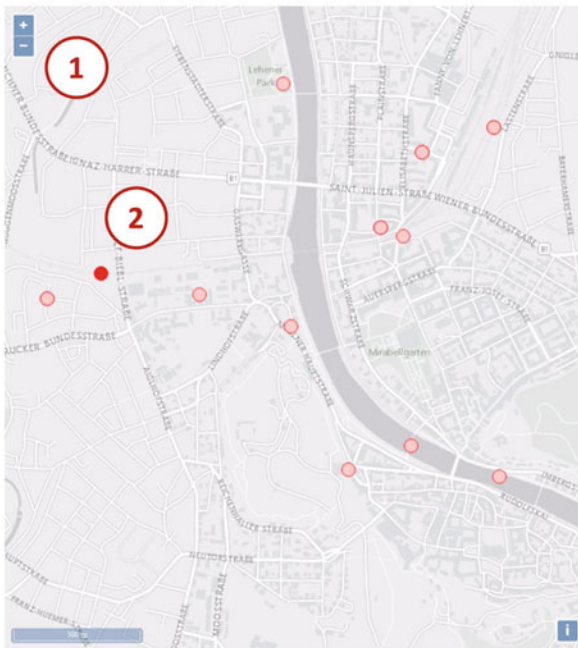
Organizing the city and the state in primary education: In an analog mapping experiment by Gryl (2015), children aged between 8 and 11 years were given the task to draw their functional fantasy world collaboratively (cf. Odenbach 2011) on a floor-covering paper with a few predefined imagined continents. They added natural conditions (including terraforming), settlements, infrastructure, and economy. They split up in groups that were each focusing on one continent or country each. The experiment resulted in a geopolitical game, starting with border controls when a child wanted to collect crayons lying on another part of the world, and ending with arms race along the borders of neighboring groups. So, beside creative and clever outcomes of functional world economies within the lollipop harvesting business, an anarchic and/or violent tendency appeared as well.

Reception and Critique

The approach of education for Spatial Citizenship has been expanded in several directions. One has been to link Spatial Citizenship and critical thinking (Carlos and Gryl 2013; Gordon et al. 2016). Another one has explored the implications of specific use gaps between genders and the benefits the Spatial Citizenship approach can draw from feminist and queer perspectives (De Luca et al. 2015; Ferber et al. 2016). In addition, the Spatial Citizenship approach has also informed participatory design initiatives based on youth mapping projects of the city (Hennig and Vogler 2016).

In early versions of the concept, both the conceptualization of citizenship as well as the radical constructivist aspect of the Spatial Citizenship approach were questioned, noting that the basic conception was easily misunderstood as fostering

#Notmysymbol - aktuellste Bilder



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Educational Resources, Geographical Information, Geomedia, and Learning, Fig. 3 Results of the collaborative mapping process, city of Salzburg (Austria) displayed on a mapping application prototype: (1) delivering a map interface including all collected symbols, (2) highlighting the selected post, (3) showing the photo of the

selected post uploaded to Instagram, and (4) delivering the location, the direct link to the original Instagram post and embedding the comment added to the Instagram post by the uploading user (screenshot from the mapping application prototype)

a very conservative aspect of administratively bounded citizenship, and even fostering nationalist tendencies. While Gryl and Jekel (2012) already based their original work on the idea of an actualized citizenship by Bennett et al. (2009), further clarifications on useful concepts of citizenship have been provided by Bednarz and Bednarz (2015), Jekel et al. (2015), as well as Gryl et al. (2017). The latter contribution also discusses a possible normative background in some more detail. Gordon et al. (2016) in addition hinted at a wider conception in their work – rejecting the notion of the powerful map user as the aim of Spatial Citizenship education and instead arguing for the contribution of Online and VGI mapping strategies being a contribution to the formation of the political subject. This can be considered to be an idea to be followed in education initiatives in future.

Another recent development and widening of the Spatial Citizenship approach has been the connection towards innovation and innovativeness (Jekel et al. 2015; Scharf et al. 2016). Here, the role of geomedia in reinventing the world is discussed, both in the technical as well as in the social sphere, and empirical research into support systems has just begun (Jekel and Lehner 2017).

The above examples of learning environments, however, show that the basic ideas of the spatial citizen approach – a minimal set of technical competences, the ability to reflect on individual, collective, and economic geomedia use, and the ability to communicate to a wider society can actually be reached with the technologies available. The approach of Spatial Citizenship education therefore is the humanities equivalent of the Spatial Thinking approach for science education.

Spatially Enabled Learner: Geomedia as an Integrated Education Platform

Among others, Thielmann et al. (2012) and Vogler et al. (2012, 205) state that we live in a “spatially enabled society”: Spatial representations are omnipresent and provide information layers for everyday information and decision-making. While the availability of mobile devices, the mobile web, social web applications, and globalization outcomes in general seem to support de-location in everyday understanding and action (Gryl et al. 2017), the combination of these aspects with geolocation technologies leads to a “renaissance of place” (Schroll et al. 2007, 26, transl.) that utilizes the information that is linked to a geographical reference. Information for many purposes in life are georeferenced, for instance, information on everyday transportation, consumption, and leisure activities.

Spatially Enabled Learning is an approach that utilizes the omnipresence of (digital) maps in order to improve learning while taking into account the communicative and collaborative potential of the current geoweb, i.e., the ubiquitous usability and continuous reproduction of geomedia via handheld devices. Inspired by the variety of content added with georeferences in everyday life enabled by geolocation technologies, from political issues (e.g., The Hoax Map) to sustainable consumption (e.g., Mundraub), Vogler et al. (2012) developed this term by identifying learning with spatial representations as added value for several subjects beyond classical geographical topics. Typical learning examples within this approach are learning about places mentioned in novels, about statistics concerning countries and regions, and about cartographic narrations on product chains.

Spatially Enabled Learning environments may “bridge the gap between everyday social geocommunication and collaborative learning environments in education” (Vogler et al. 2012, 209). The approach “aims at the integration of communication and geo-technological tools into a state-of-the-art (e-)learning framework” (Vogler et al. 2012, 205). This includes that learning content is not only spatialized/georeferenced by teachers but also by learners, who communicate

themselves. For this purpose, in accordance with Vogler et al. (2012), it is suggested to use simple representations – online mapping tools such as used in the Spatial Citizenship approach, supported by everyday technology (mobile devices).

In sum, “Spatially Enabled Learning makes use of web-based spatial representations to support interaction, communication and document learning outcomes in educational contexts by connecting complex learning content to a spatial dimension. This can be achieved by contextualisation, by cartographic support of arguments in communication processes or simply as a spatialized portfolio that may be either individual or collective or both.” (Vogler et al. 2012, 206).

Basic Concepts

Spatially Enabled Learning is a concept primarily designed for providing an added value to learning. In contrast to the Spatial Citizenship approach, the main aim is rather individual and collective gaining of insights more than public communication and convincing others. However, Spatially Enabled Learning is a valuable basis for understanding the spatial aspects problems and a starting point for acting as a spatial citizen. Furthermore, competences developed as spatially enabled learners are fruitful for societal participation as well. The approach bases on two main theoretical references: (1) relational spaces and (2) dual coding.

- (1) Spatially Enabled Learning clearly bases on the idea of the attachment of meaning to physical matter by communication through spatial representations. At this, the meaning is represented by learning content that can be georeferenced. Mainly, this approach refers to representations of geographical spaces (for instance, a map of places that shows indicators/results of climate change, or fictional events in novels taking place in existing cities), but apart from this, all representations that use spatial relations, including fictional landscapes (e.g., map in the Lord of the Rings), are useable. The main aspect is that meaning/content, and therefore spaces are regarded as socially constructed.

(2) Maps address the dual coding functionality (Paivio 1990) through a combination of pictorial (maps as picture) and symbolic elements (maps as text) that target at different modes of information procession in the learners' reception, as described in mapping theory (Wood 1993). The usage of two channels at the same time refers to the added value for memory and learning that pedagogical psychology notices when text and pictures are combined (multimedia principle, Weidenmann 2006; Schnotz 1995). On the web, mashups lead to the combination of several sources of information and modes of representation, so that dual coding functionalities are nowadays transformed into multicoding. Enemark and Rajabifard (2011) describe the link between analog codes (learning contents) and symbolic codes (spatial representations) with a positive effect on the memory and understanding of complex information as another aspect of maps that might run under the dual coding label.

Furthermore, the combination of information with location – a spatial contextualization – supports learning as well as methods in mnemonic training (Krämer and Walter 2006). Similarly, map information supports the understanding of complex, nonlinear relations (Wood 1993). Apart from that, current spatial representations on the web combine the duality between individual and social construction of meaning.

Moreover, Spatially Enabled Learning refers to an inclusive component: The code system of mapping that uses pictorial elements, and, particularly in simple web mapping, a quite consistent and broadly used design, supports communication beyond cultural, language, and literacy barriers (Hall and Jones 2012). “Communicating via spatial representations may bridge learning contents beyond learners' verbal skills and (dis)advantages.” (Vogler et al. 2012, 206). Therefore, Vogler et al. (2012) closely link this approach to social geocommunication which means the communication with the help of spatial representations that may be utilized for learning purposes, both concerning information and hypothesis

construction for the single learner, and production of content and collocation for learning teams.

Exemplary Learning Environments

The Spatially Enabled Learning approach is useable for all learning content that can be visualized in spatial representations, which means all georeferenced content with potential interest for gaining insights in formal and informal learning processes.

In the project “Tripping Stones in Landau – histories of people,” students of a middle school (Integrierte Gesamtschule Landau) mapped tripping stones (Stolpersteine) that shall keep up the remembrance of the victims of the Holocaust in their home town Landau (Pfalz, Germany) using Google Earth. This example, conducted in collaboration with one of the authors of this paper, is situated in the field of history education, as the students searched in the municipal archive for information about these people. While doing so, they learnt about the enormous crime that made these people victims but also about their lives they had before. These everyday historical narrations give the partly persons back their identities and faces. Students located the tripping stones, placed them on a map, and added the biographic information they had investigated. The map was published on the school website. This act of geovisualization is an example of Spatially Enabled Learning, as different modes of representation were addressed and a layer of history was put on the town. This layer illustrates that the victims of the regime once have been omnipresent and fully integrated into the town – their presence and the knowledge of their extinction gives another insight into the terrifying dimensions of the Holocaust. Similar learning environments have been developed by Schellenbacher (2017) as well as Wöhs et al. (2018 in print) (Fig. 4).

Mapping fair trade facilities: Vogler et al. (2015) conducted a mapping project named Youth Map 5020, which contained, among others, digital mapping of fair trade shops in the students' home village. Students did not only practice the method of mapping nor did they not only draw societal attention to the concept of fair trade, but they also built a profound basis to learn about fair



Educational Resources, Geographical Information, Geomedia, and Learning, Fig. 4 Students' mapping of tripping stones in Landau – geovisualization in history education, Integrierte Gesamtschule Landau

trade (definition, different labels, categorization) and to gain more insight (distribution of shops in correlation with location factors) (Fig. 5).

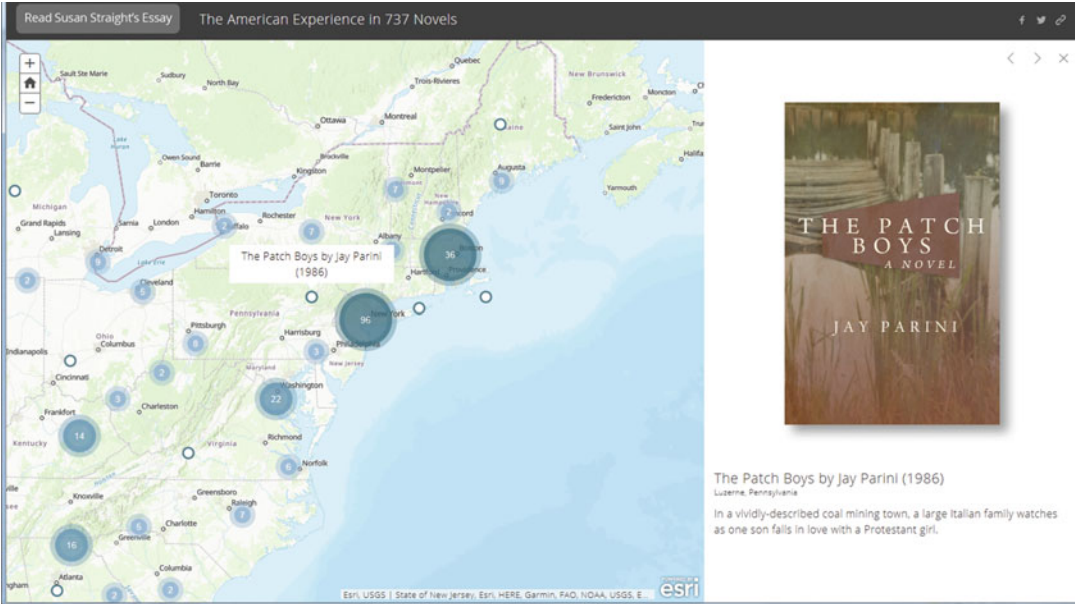
Platforms that could be used for Spatially Enabled Learning still need more development, including partnerships with the industry, and should combine functionalities of traditional learning management systems with cloud-based mapping and communication tools to contextualize most learning materials, learning outputs, and additional information. The outcome would be a spatialized portfolio that could be both individualized and also collective in terms of classroom practice, showing not only locations of learning, blind corners but also spatial concentrations of individual knowledge production.

Conclusion and Outlook

As it has become clear in the discussion of the four approaches above, they differ significantly in terms of aims, stakeholders, learning theories

and epistemology, concepts of space, pedagogical approaches, and the roles and capabilities learners should acquire. With the advisable exception of a purely technical perspective based on software learning, all approaches can be seen as useful structural components in secondary education (Table 1).

Two dimensions particularly link into each other: learning theories and concepts of space used. Spatial thinkers derive their insight from using absolute space and spatial laws, while spatial citizens are based on the assumption of socially constructed, relational space. It has been argued that this differentiation is responsible for their rootedness in the sciences and humanities domain, although it can also be linked to the concepts to moderate vs. radical constructivist perspectives of learning. This can be traced to the respective pedagogical approach used. In the sciences, and therefore Spatial Thinking domain, model- and problem-based learning are used, while for the education of spatial citizens, inquiry based-learning,



Educational Resources, Geographical Information, Geomedia, and Learning, Fig. 5 Susan straight's' The American Experience in 737 novels, story map. <https://storymaps.esri.com/stories/2017/737-novels/index.html>.

The story map here looks into the local embeddedness and spatial context of literature – a model for learning materials in general

Educational Resources, Geographical Information, Geomedia, and Learning, Table 1 General outline of geomedia-based learning approaches

	Technical perspective	Spatial Thinking	Spatial Citizenship	Spatially Enabled Learning
Aims	Workforce development	Science education	Citizenship education	General learning
Stakeholders	Industry	MINT-subjects	Humanities	General pedagogy
Learning theory	Behaviorism	Moderate constructivism	Constructivism	Constructivism
Concepts of space	Absolute	Absolute	Relational	Absolute and relational
Pedagogical approaches (examples)	Software learning	Model-based learning Problem-based learning	Inquiry-based learning, project based learning, activist education	Locational games, spatial portfolios
Role of geomedia/ geoinformation	Technical system, software	Organizing phenomena in absolute space	Tool for reflection and communication through power relations	Organizing and supporting general learning spatially
Roles of learner	Technical user	Spatial analysis, technical research and development	Activism and participation, political subject in society	Spatially organized member of society
Authors	Kerski (2003)	NRC (2006)	Gryl and Jekel (2012)	Vogler et al. (2012)

project-based learning, and activist education are more common.

It is suggested that Spatially Enabled Learning will become the norm across subjects, just as

Google or Wikipedia nowadays also provide the possibility to organize much of their information spatially. The technology is available. Currently, the providers of learning management systems,

however, have not jumped the train, while software companies like ESRI would easily provide the necessary solutions in terms of online mapping and communication.

In future, expect many learning processes to be spatially enabled following the everyday localization of information, services, and activities with the help of digital devices and geolocation technology. Within Spatially Enabled Learning environments for general education, the concepts of Spatial Thinking for science education and Spatial Citizenship for citizenship/humanities education will perpetually apply as inevitable aims of an education that utilizes geoinformation. They can be considered a reasonable and sustainable basis for geomedia-based education across subjects in the respective domains.

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Educational Resources, Hypermedia

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Synonyms

[Hypertext](#); [Images](#); [Nonlinear navigation](#); [Sounds](#); [Texts](#)

Hypermedia in a Nutshell: Historical Landmarks

Hypermedia, in short, relates to a *new kind of resource* that links several kinds of documents (texts, images, sounds), allowing easy nonlinear navigation through the material. But this is only one view of a more complex matter. In what follows, some historical indications shall be given, and then the case of hypermedia for education will be analyzed.

It is generally assumed that the idea of hypertext dates back from Vannevar Bush, at the end of World War II. In his seminal paper (Bush 1945), he presents the new perspectives offered to mankind by technology and imagines a future using the new potentialities of machines for intellectual tasks: computation, manipulation of ideas, selection of the right data, etc. Stressing the fact that the ability of associating is at the core of the human minds, he describes a visionary artifact (the “memex”), using technology known at that time, that would allow, with microfilms, dry photography, etc. to perform “associative indexing” between documents, tying together permanently

different items. This would allow users to form and to memorize trails of associated items.

It is also generally known that the implementation of such an idea is largely due to two other thinkers: Doug Engelbart, pursuing a lifelong quest of “augmenting” the human mind, designed a system called NLS/Augment (Engelbart and English 1968). Ted Nelson, who is credited with the invention of the term “hypertext” (Conklin 1987), developed a system named Xanadu that implemented clever ideas such as the difference between “content links” and “transclusions” (“connections between things which are *the same*”) (Nelson 1999).

Hypertext and hypermedia were therefore actually born before the invention of the World Wide Web, at the end of the 1980s. After that date, links did spread everywhere, and the word “navigation” enriched its spectrum of meaning with a travel on an ocean of data. Quite interestingly, the denomination of the software allowing this navigation is “browser,” which comes from a whole different semantic field.

Ted Nelson remarked in his 1999 text that what the Web implemented was a small part only of the potentialities of hypertext: “The World Wide Web was not what we were working toward, it was what we were trying to *prevent* [...] Its one-way breaking links glorified and fetishized as ‘websites’ those very hierarchical directories from which we sought to free users, and discarded the ideas of stable publishing, annotation, two-way connection and trackable change.”

The undeniable reality of that time has however changed a lot with the apparition of systems dynamically generating content and able to adapt to the user’s profile, as exemplify today search engines.

Hypermedia in Education

In education, the interest for hypertext and later for hypermedia surged in the 1980s. Basically, what a hypermedia offers is the opportunity to follow a path on a graph of situations or resources, each node giving access to a set of another ones (those implemented by designers of the system).

The idea of hypermedia now seems very natural, on account of the enormous dissemination of the *World Wide Web*: nowadays, nearly everyone assumes, when seeing a blue and underscored text on a screen that a *link* is hiding behind it and that, by clicking on it, one should be transported to some other document, which should have a logical relation with what the text indicates. The same is true also with clickable images.

This is in a way very similar to computer-assisted learning, but the major difference stems from the fact that the transition between nodes is not at the initiative of the program but depends on the user's choice. Such an environment is therefore supposed to be in accordance with the principles of constructivist learning. Many research works have been done on the effects of using hypermedia as a way to explore and to learn a domain, the risks of disorientation in the cyberspace being pointed very early.

In a review, Bruillard and De La Passardière (1994) observed that, in education, hypermedia may act either as cognitive tools for discovery learning, allowing learners to browse and restructure information (in the line of micro-worlds popularized by researchers like S. Papert around the LOGO language (there is a great intellectual continuity between LOGO and the modern systems like Scratch aiming at facilitating programming by young children.), or as tutors (but then they encounter the classical and thorny problems of maintaining a good cognitive model of the learners).

With the spread of the Web, everything offering a hypermedia side, a new interest toward the use of adaptive hypermedia surged in the 1990s. In a later review, Brusilovsky (1996) presented different forms of adapting the Web to users' profiles (text shown, direct guidance, adaptive sorting, hiding and annotation of links, multimedia presentation, map, etc.). His paper stresses the fact that it is promising to let users adapt the presentation and take into account those changes and forecasts the importance of the Web.

In October 2017, a search on *Google Scholar* with “hypermedia” and “education” as keywords showed that the number of references has known a steady yearly growth (from 600 in 1990 to 7600 in 2015). When hypermedia was replaced by “adaptive hypermedia,” the fraction of results, which was below 1% in 1990, grew to more than 10% after 2003. This confirms the rise of a new interest in adaptive environments, whatever be the principles underlying them.

Things keep on moving. Computer tools have now become a commonplace. They help humans

(and also constrain them) in every activity they lead. Being banalized, hypermedia has lost its innovative side. But it lingers on. Modern systems allow everyone to propose new associations in large data repositories and to offer users opportunities of discovery. Hypertext is at the core of the matter, allowing to associate strings of text with other texts that may point toward multimedia resources. Its adaptiveness now relies on new algorithms exploiting “big data” and creating profiles for users according to the traces they left, based on algorithms comparing individual profiles with those of a mass of others. However, if this approach now seems to work quite well in marketing, for adjusting commercial platforms, it is far more difficult to adapt it to education.

Cross-References

- Educational Resources, Geographical Information, Geomedia, and Learning
- Formats of Virtual Learning
- Open Educational Resources and Distance Learning, Challenges and the Way Forward in Higher Education

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Educational Support

► [Educational Support on Computing and Informatics for Disadvantaged Groups, An Empowerment Perspective](#)

Educational Support on Computing and Informatics for Disadvantaged Groups, An Empowerment Perspective

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Synonyms

[Computing and informatics](#); [Educational support](#); [Empowerment](#); [Social inclusion](#); [Socially disadvantaged learners](#)

Introduction

Global dissemination of information and communication technologies (ICTs) was supposed to lead to development and reinforcement of global democracy. However, despite the global dissemination of ICTs, realization of equitable enjoyment of its benefit is still seen problematic. Instead of promoting democratic values through the dissemination of ICTs, the digital divide has been reported emerging and widening (Revenaugh 2000).

Accordingly, this article explains how “educational support on computing and informatics for disadvantaged groups” has been understood and investigated as an academic topic in pursuit of promotion and improvement on empowerment activities in this field exercised in real societies. The topic, rooted on a context of research on computing and informatics education among citizens, represents a social concern to be addressed for realizing a social circumstance called “knowledge society” allowing every individual to

equitably participate in as an active member playing a role of knowledge creation. Despite emphasis of academic research put upon computing education mainly in schools, supporting broader range of individuals in learning and enjoying computing and informatics has been grappled with in terms of both social activity and academic research, from a viewpoint of civil empowerment (Saito 2017). Recent social transformation caused by the emergence of knowledge society, which was enabled by a massive use of digital technology in society, enlarged significance of the topic regarding a practical concern linked to actual practices on computing and informatics education among a nonformal learning sphere. A basic concern of the researches on the topic is generally put upon how individuals’ well-being can be improved through the educational support. Concerning disadvantaged groups in current societies, their disadvantage, which is linked to social, economical, and political participation, as the lack of capacity to utilize potentials of computing for their own knowledge creation, is supposed to get larger today, which means they are at risk of being excluded from freedom of social participation. Therefore to support disadvantaged groups’, social participation through helping them in learning computing and informatics becomes inevitably a central mission which calls for various attempts in this field.

Background

Shared Recognition on the Digital Divide and Demand for Social Inclusion

Actual engagement on the topic of “educational support on computing and informatics for disadvantaged groups” started practically and theoretically motivated by a recognition shared by the study on the digital divide that approaching the digital divide should be based on the conception of empowerment. With regard to discussion on how to address the digital divide, current focus of the discussion has shifted from achieving equal access to ICTs with providing physical infrastructures toward delivering equitable opportunities for individuals to enjoy substantial improvement of

well-being through empowerment on technology use (Revenaugh 2000). This shift of discussion reflects the fact that just having “access” to ICTs is not sufficient for fulfilling various life demands which well-being of individuals comprises. Empirical researches on the digital divide have revealed the attributes and background factors that may affect individuals’ disparity not only in access but also in use of ICTs, which are, namely, race, ethnicity, gender, class, educational background, and other factors relating to the socioeconomic situations (e.g., Kvasny 2006). These attributes and factors commonly reflect social, economical, cultural, and historical circumstances of the society, which may form social circumstances inviting the disparity between the rich and the poor among citizens.

Results of prior research have brought about the shared recognition that approaching the digital divide should be based on the conception of empowerment. The empowerment in this context is directed toward fostering human capacities for living well through making good use of ICTs (e.g., Gigler 2011). The conception of empowerment as a basis for tackling the digital divide can be applied to the situation not only in developing countries but also in developed countries, since it is common for both of the countries to have social structures reproducing socially disadvantaged groups at risk of being excluded from informatized situation of society based on digital technologies. In terms of the empowerment for such members in society, the problem of digital divide can be understood intrinsically as a subset of so-called social exclusion, which is asking for promotion of equitable opportunities for digital participations (Wei and Hindman 2011). This means it is crucial to construct a blueprint of social inclusion into informatized situation of society under the circumstance of the globalized digital divide.

Indirectness Between ICTs and Well-Being as a Target for ICT4D

Findings of the study on information and communication technologies for development (ICT4D) also gave important knowledge toward the research on the topic of “educational support on computing and informatics for disadvantaged

groups.” Many of the literatures on ICT4D insist on the indirectness between ICTs as technological input and enhancement of the residents’ well-being as its output. Through the research on ICT development for rural communities in Bolivia, Gigler (2011) emphasized that no direct relations had been found between improved ICT access and enhanced socioeconomic development. In addition, using the notion of “catalyst,” Gigler argued the significance of “intermediary organizations” in converting ICT access into “meaningful use” of ICTs through educational support for the rural poor citizens. With the model of the ICT4D value chain, Heeks (2010) also argued the indirect relationship between ICT infrastructure and development impacts, which indicated the ICT access should be seen as merely a “starting point in understanding ICT’s contribution to development” (Heeks 2010).

The problem of the indirectness between ICT access and enhancement of residents’ well-being is supposed to be common toward the developed countries where ICT diffusion has mostly been completed. This indirectness is basically affected by the social structure reflecting inequality and inequity in obtaining learning opportunity of computing and informatics, which is seen not only in developing countries but also in developed countries (e.g., Kvasny 2006). Though the state of basic literacy is generally better in developed countries, the distribution of learning opportunities to convert ICT access into meaningful use of ICTs is still left to be insufficient.

Furthermore, the research on “educational support on computing and informatics for disadvantaged groups” is basically asking about the roles of computing and informatics education on the disadvantaged citizens’ empowerment in knowledge society. The preceding arguments (Hromkovic and Steffen 2011) have shown the roles of such education in introducing fundamental concepts of computing and informatics and in expanding human capacities necessary to utilize ICTs effectively for various purposes. The arguments also have reported that expanding such capacities enabled people to produce systematic ways of problem-solving with ICTs and to create representations reflecting their own ideas. The

role in expanding career choice with the enhancement of computing skills has also been discussed in some literatures (e.g., Hromkovic and Steffen 2011). There is, in addition, an argument which illustrates the educational role in promoting democratic participation, being considered as a basis of public education, through encouraging creating programs to contribute to others in the society (Schulte 2013).

However, the role of computing and informatics education hasn't been investigated and discussed adequately yet, especially in terms of empowering disadvantaged groups living in informatized situation of society emerging in the developed countries. It is believed that such investigation and discussion will add an alternative view of computing and informatics education's contribution toward the realization of digital equity.

A Case of Field Research: Educational Support on Computing and Informatics in a Group Helping Disadvantaged Young People's Social Participation

The topic of "educational support on computing and informatics for disadvantaged groups" can be understood better with a report of a case study conducted in a real empowerment activity. As an instance of such a report of the case study, Saito (2017) reported outcomes of a research conducted in a group, placed in a mid-sized city in Japan, which was organized to help social participation of disadvantaged youths. The research was conducted in pursuit of the research question as follows:

- What kind of possibility and limitation can be found in educational support on computing and informatics for socially disadvantaged youths in developed countries as a means of empowerment and social inclusion?

In the following parts, the outline of the research and reported findings presented in the article of Saito (2017) will be introduced to show how the topic may be researched and what

kind of outcomes may be obtained in such a research.

Research Question and Methodologies

According to the article, the purpose of the research is set to advance understanding of the significance of promoting learning opportunities of computing and informatics in terms of civil empowerment and social inclusion. Consequently, the research methodologies are explained as follows; to explore the research question, the author of the article joined a group's activity to help rehabilitation and social participation of the pupils and students with school absenteeism and the youths who had experienced socially withdrawal. The group was placed in a mid-sized provincial city in Japan. The group's size had varied during the research period; however, there were around five to ten young people with two to five staff members including part-time supporters. The author acted as a part-time member mainly to support such youths in getting familiar with computing and in learning something about computing and informatics. As a data collection, the author had made a series of text descriptions with some pictures and movies in the field that the author thought as field notes, noting events and occurrences, dialogues with group's participants, findings and interpretations, and reflections on every session during the research period. The data were analyzed into important themes and issues in accordance with the research question. This process was supplemented with further observations and dialogues in the field.

As described in the article, the research was to be conducted in May 2015, after a period of pilot study in the same field from December 2013 to January 2014. The article was published based on the findings of the analysis of the field notes taken from May 2015 to March 2017. During the period, the author and the young people in the group had been involved in learning introductions of computing and informatics with several practices, such as making games, teaching elderly people programming with Scratch, and constructing a programmable robot called "MugBot" (it is a non-proprietary open-source social robot originally

designed by Koike Laboratory in Tokyo Metropolitan University. <http://www.mugbot.com>).

The research followed the basic conceptions of action research as a participatory research methodology. Action research is explained as an approach “that enables people to find effective solutions to problems they confront in their everyday lives” (Stringer 2013) by collaborative commitment toward real social problems for a group of people that are relevant to the problems. In this methodology, the researcher is not merely an objective observer but a member who actively participate in the process of problem-solving. Moreover, the research process is interpreted as a process seeking for positive social change based on democratic values. The conception of action research was suitable for the research in pursuit for the shown research question, which called for practical engagement in an educational support project practiced in a real context of a developed country.

The Reported Findings of the Research

While joining the group’s activity, the author of the article had met certain amount of young people who were at various ranges of the ages (from elementary pupils to late 20s). Among the members the author had built a continuous relationship with some young people who were supported in the group for their rehabilitations. They were all the age of late 20s who had experienced the status of social withdrawal in years past and hadn’t have any opportunity of regular employment.

Based on the reflection and interpretation of the involvement with them, which had been noted in the field notes and other visual materials, the author reported in the article these suggestions shown below relating to the possibility of educational support on computing and informatics.

- With some triggers (e.g., suggestions on the joy of making games with programming, the way of obtaining teaching materials and other useful information in the web, and the annual event on Scratch programming) brought by the author, the young people got interested in using computers in more creative ways and autonomously engaged in learning computing.

- The young people were also motivated to learn introductory part of informatics and succeeded in finding the joy of learning it.

During the period that the young people were learning and practicing computing and informatics in the group, they enjoyed the chances to communicate with others (e.g., support staffs, other young participants, neighboring residents participated as volunteer supporter, and the pupils and students of the schools around) for their capacities of computing and informatics.

For instance, the author had noted in the field notes the circumstance in which the group’s members had decided to engage in constructing MugBot. According to the article, one of the main factors which driven the members to engage in constructing MugBot was supposed to be intellectual and emotional stimulation they obtained from a social event on Scratch programming held annually. They had been informed of the holding of the event from the author and had decided to attend it by their own decision, which described how the members’ emerging interests into creative aspects of computing had involved them into learning computing.

After that, the young people had begun to construct a unit of MugBot and kept their effort to complete all of the process of construction. Then they finally succeeded in completing the construction and controlling all of the basic functions (blinking eyes of LED, voicing given text data, and moving its head according to given programs) 3 months later from the beginning of the construction. While they were engaged in it, they supposed to learn controlling devices with programs and had experienced constructing an example of network system, which requires basic understanding of the Internet Protocol, merely with a textbook and other resources they found themselves. Very occasionally, the author of the article gave advices when they seemed to get into difficulties that might be beyond their capacities.

Moreover, their capacities of computing and informatics had become a cause of generating new communication with others visited their working space. For instance, when the group accepted some students of a junior high school

located near the group's space for the students' work experience program in the school, one of the young people had autonomously attempted to introduce making programs with Scratch toward the students. To the author's eyes, the time the student had spent for the work experience program seemed to become more meaningful and more pleasurable for it.

The author of the article also found these suggestions, as a result of reflection on the field notes, concerning limitations of educational support on computing and informatics.

- The young people's expanded capacities of computing and informatics didn't seem to expand obviously their motivation for making use of such capacities for their social participation to improve their personal situation in the surrounding society.
- Their motivation for making use of such capacities to improve circumstances of the community they belonged to also didn't manifest itself in their behavior.
- It seemed difficult for the group members (including the support staffs) to convert efficiently such capacities they had made into the group's competence.

With regard to the first and the second points, the author of the article faced the young people's strong refusal on engaging in the activity that requires being social. Together with that, the author reported "social" nature of programming, which means creating programs that can afford someone a certain level of convenience, as it inevitably requires consideration on others' convenience.

The incident in the field on which the author's consideration grounded was that one of the young people showed negative attitude toward the author's offer of creating a program based on her/his own or the group's needs of computing. The young people were quite positive when she/he had learned and reproduced programs according to some situation settings given by the textbooks. In addition, the young people seemed to have enjoyed learning an introductory level of

informatics with making programs according to the instruction in the textbooks. However, the young people had consistently expressed his indifference to create something which could be a solution for "real problems" concerning her/his personal or the group's daily activities making use of his capacity of computing.

The third point had related to the limitation of the members' participation in the educational support on computing and informatics. The group was mainly managed by two core staffs, who were the manager and the co-manager of the group, with the help of several volunteer staffs (one of the young people had changed her/his position in the group from a supported member toward a volunteer staff during the research period. She/he had been virtually supported in her/his social participation while working as a volunteer staff). In the author's view, they had had a shortage in staffs for the amount of their tasks, which made it difficult to involve themselves into the practice of computing and informatics as much as they could develop their own educational support programs by themselves.

The author of the article reported that he and the staffs had provided various occasions for the young people to encounter the practice of computing, mainly with Scratch programming as an introduction. And the author also noted that many of them actually seemed to be interested in practicing computing. However, the membership of the young people had not been stable because their participation in the group was basically left to their own circumstances, which were sometimes too complicated socially and personally to keep attending the practice.

Suggestions on the Educational Support Based on the Field Research

The Possibilities on the Educational Support Found on the Field Research

Based on the findings of the research conducted on the group supporting disadvantaged young people, the author of the article of Saito (2017) presented suggestions regarding the possibilities

and limitation on educational support on computing and informatics for such young people, in accordance with the research question shown above. The suggestions on the possibilities are as follows:

1. Such support can expand the mode of disadvantaged young people's daily use of ICT facilities.
2. It also can derive their desire for personal challenges of autonomous expansion of their computing capacities.
3. It can enlarge the young people's communication opportunities with others around.

According to the article, the possibilities found on the field research can be illustrated by the three suggestions shown above. The suggestion one tells about the expansion of the daily use of ICTs happened on the young people who joined the educational support. That is, the young people in the observed group had successfully learned to enjoy utilizing ICT facilities in more creative ways with programming, whereas they at first had very limited idea to utilize them because of their limited learning opportunity for the personal and social circumstances. The suggestion 2 shows young people's autonomy in expanding their computing capacities. This suggestion explains a possibility of the educational support to promote the autonomous behavior in learning computing among the young people. Actually, such autonomous behavior was reported in the article, which had commonly been observed among the young people's usual practices during the research period. The suggestion 3 describes an aspect of communication expansion brought about among the young people through participating in the educational support. As the author in the article reported, such communication opportunities were observed among the young people and also in the relationship with the people surrounding them, such as the staff members, volunteer supporters, visiting residents living nearby, and so forth, which had occurred in the context of computing practices.

Limitation on the Educational Support Found on the Field Research

The author of the article also presented the suggestions obtained regarding limitation of the educational support. According to the article, the limitation is classified as follows:

1. The educational support cannot turn disadvantaged youths' expanded capacities of computing directly into the ideas of applying it toward real problem-solving activities in social situations.
2. It also cannot enhance the youths' motivation for utilizing their computing capacities into strengthening their connections with societies around.
3. It cannot function without continuous help of volunteer supporters who have computing capacities and are ready for work with practitioners in the field.

The suggestions on limitation represent the problems regarding the educational support which should be solved in terms of sustainable empowerment for disadvantaged young people's social participation. The suggestion 1 refers to the limitation on conversion on acquired skills and knowledge into the capacity to solve social problems regardless of its scales. This problem is supposed to relate to difficulties with attracting the young people's interest in problem-solving in the real world. In the article it is reported that the young people had consistently shown quite reserved attitudes to engage in solving problems relating to the group's activities utilizing their computing capacities. The suggestion 2 focuses on the limitation on involvement of the young people with social relationships. The research outcome suggested the educational support had very limited influence on building the young people's motivation to make use of their expanded computing capacity to find and get involved in new social relationships available to them. For the young people reported in the article, strengthening of the connections with societies in this term had potentially contained seeking jobs, attempting to learn in higher education, creating the group's

new activity to contribute toward neighboring communities, and so force. According to the article, in the research period, any obvious incidents relating to these hadn't been observed. The suggestion 3 describes the limitation on sustaining the educational support only with the group members' effort. Planning and running the educational support requires expertise in computing and informatics and also the knowledge and skills on pedagogy in computing and informatics, to some extent. In the reported research, the author participated into the group's activity as a volunteer supporter and collaborated with the group stuffs to realize the educational support. However, as far as the reported research period, most part of the educational support in the group had maintained mainly with the author's participation.

Conclusion

The suggestions obtained from the research reported in Saito (2017) lead to two conclusions. The first conclusion is that premising collaboration of the practitioners of both computing and social participation support backgrounds, educational support on computing and informatics for disadvantaged young people in developed country has a certain potential of expanding their choice of "meaningful use" of ICTs, which is used following Gigler's (2011) viewpoint, with deriving autonomous participation in computing practices. This conclusion is consistent with the recent tendency of digital divide research which emphasizes the gap of "meaningful use" rather than "physical access" as a key factor of approaching inequitable circumstances of ICT use (e.g., Wei and Hindman 2011). Moreover, this conclusion corresponds with an ICT4D's evaluation framework, the "Choice Framework" proposed by Kleine (2010), which argues the significance of small case development studies on ICTs' role of expanding freedom of residents' choice as empowerment (Heeks 2010).

The second conclusion is that the educational support cannot be the solo factor to encourage them in their social participation through

utilizing their computing capacities. It is supposed that there will be a limitation within such educational support in terms of empowerment for social participation if computing and informatics are to be taught and learned merely as a value-free decontextualized knowledge by the learners. In other words, potential of the educational support to overcome the "indirectness" between ICT access and enhancement of residents' well-being should be understood restrictedly for the present state of the research in the field. This result is consistent with the indication made by Gigler (2011) that "improving the access to resources for the poor, for instance providing access to girls' education or access to ICTs only represents a potential for enhancing their capabilities and thus does not automatically have to lead to positive outcomes on empowerment."

Nevertheless, this does not mean educational support on computing and informatics is absolutely unsuitable for the empowerment of disadvantaged young people's social participation since there is room for improvement in its pedagogical design to link the supported young people with the context of surrounding societies through utilizing their computing capacities. It is able to be interpreted that the shown limitation rather signifies a demand for the educational support designed based on more social and contextual conceptions that can afford the supported young people an idea (or ideas) about engaging with societies utilizing their computing capacities. In this direction, Schulte's literature (Schulte 2013) will be one of the bases to pursue the possibility of computing education in the light of learner's social participation.

The attempt on realizing educational support on computing and informatics for disadvantaged young people will continue with the purpose of investigating further effect on the young people and also on the practitioners on supporting young people's social participation. To make further attempt fruitful and contributive for the problem, these insights are derived as recommendations for the continuous educational support; practices in the support should be designed considering involving the young people into computing in

social context so as to make more opportunities to link their capacities toward real needs of computing; the “real needs” for computing capacities should be explored under the dialogical relationship among the young people, the practitioners helping young people, and the computing and informatics educators; for the pursuit of sustainable support, an institutional framework to include organizations supporting young people into decent computing culture should be explored. In other words, more holistic support, containing some active problem-solving projects utilizing computing capacities, for instance, that enable the supported young people to find the meaning of learning computing in social context, should be explored and practiced for further empowerment.

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Educational Technologies

► [Distance Learning](#)

Educational Technology

► [Computer-Based Training and School ICT Adoption, A Sociocultural Perspective](#)

Educative Value of Digital Storytelling

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Synonyms

[Digital literacy](#); [Narratives](#); [Stories](#); [Story telling](#); [Video making](#)

Introduction

While the “digital” modifier has an outsize influence in suggesting the engagement, relevance, and ultimately, educative value of storytelling, we want to take a deliberate and critical analysis of these concepts to firmly establish the credentials of this practice, not just as a literacy practice, but also as a means to expand the boundaries of instruction in a classroom. Here, it would appear that the public imagination is quick to suppose that anything “digitalized” is magically superior to its non-digital counterpart. Digital storytelling, or storytelling more generally, can fulfil *axiological* purposes for learning, along with creating an instructional context that can be deeply meaningful to learners. We situate these claims in the nature of stories, and the nature of knowledge itself, but nonetheless argue that the end result is

not the linear sum of these parts – while synergistic gains are possible, the possibility for interference also exists. Educators interested in this field need to be clear about the choice of components chosen, and what trade-offs they may be getting.

What Is Educative?

It is easy to forget that mass public schooling, which we most often associate with the term “education,” has not had a very long history, and that its origins and even much of its current intent has been (and continues to be) one of efficient preparation of a state’s citizens for the world of work. While this pragmatic purpose remains a legitimate one, it must nonetheless be recognized that other particularly liberatory goals for schools exist, such that job preparation remains but a subset of the possible educative goals possible for schooling. Rather than seeing schooling as a gatekeeping process of selective retention of “talent” in specialized fields of work, *education* directs us towards an increasingly wider sphere of participation in social life of the wider communities in which we live. In this regard, we need to recognize that some activities of schooling can be mis- or even anti-educative. For instance, given the high demand and perceived status of work in high technology, it can be easy to fall into the trap of supposing that any sort of schooling activity that involves rehearsal in the technologies *du jour* must benefit the student; even better if the particular technology is in active use by members of a highly paid profession. The trouble with such an approach lies, in essence, with the inherent unpredictability of the future; given the persistent preoccupation of purveyors of technologies to “disrupt” the status quo, job preparation as a goal can appear to be trying to shoot a moving target by aiming at where it used to be.

Even if job preparation were to be taken as a serious goal, it may be helpful here to consider the nature of innovativeness as a goal, given that the creation of novelty (for its own sake?) appears to underlie much of the economic drive of our times, and is likely to continue being important for some time yet. At least in the discipline of design, it has

been acknowledged by leaders and scholars (Kelley and Kelley 2013; Nelson and Stolterman 2003) that innovative advances stand at the confluence of technical feasibility, social desirability, and business viability; and that design intentionality is key to process. To expand on these ideas, we need the philosophical insights of David Hume, who noticed the essential gap between the descriptive and the normative in the field of ethics. Nicknamed Hume’s Guillotine for his observation that no description of the way things currently are have any bearing on the way things *ought* to be, we appreciate this insight if we understand that “innovations” are necessarily statements of ought. The natural sciences and associated technologies need to be interpreted as our very best means of apprehending the world, of describing nature and crucially being able to predict future phenomena. However, the natural sciences must remain mute on how best one ought to deploy these types of knowledge; technological approaches are always informed by purposes outside of the natural sciences. We saw this with a desire to uncover the workings of gods, to admire their work in times past (as in early Islamic civilization providing insights into mathematics, and early paleontology documenting “god’s creation”), to our contemporary desire for nation states to increase economic indicators of “wealth.” In other words, if innovativeness is to be a desired goal of schooling, it may be necessary for schools to not only instruct students in the oft-perceived higher status scientific and technological knowledge, but to also help students develop a more nuanced understanding of desirable intents, persuasive narratives, and philosophical rationales for wider senses of purpose. Stories are the answer to the question “Why Innovate?” – we do so not because the technology leads us to do certain things, but because stories told by innovators tell us it ought to be so.

This leaves us with a particularly interesting position on the educative value of digital storytelling: we believe digital storytelling serves not just as a means to engage students with contemporary technologies, or as an extension to well-established critical literacy approaches. Specifically, digital storytelling, or storytelling more

generally, provides students with a rich context to develop, debate, and discern the correctness of particular intentions. Digital storytelling is an education not merely in the techniques and technologies of telling a story, it is also an education in axiological persuasion, updated with contemporary technologies that affords producers and consumers of stories with media and phenomenological experiences not available to classical means of communication.

In what follows, we develop our argument by first elaborating on the nature of story. The essential contention here is that stories are always vehicles for particular axiological positions, and as with any particular value system, these values are always contextualized to time and space. We return to the above argument to discuss the nature of innovation or the creation of new knowledge, to discuss the distinction between different forms of knowledge. Here, we want to argue for the necessity of different ways of knowing in the service of education for ever-widening realms of participation. No discussion of values, narratives and identities can be complete without referencing the work of critical literacy and scholars in multimodal studies. We use some of these ideas to illustrate the significance of new media: significantly, if we agree with McLuhan and Fiore (1967/2001) that “the medium is the message,” particular media choices can connote distinct value messages too. Finally, to conclude, we discuss some pragmatic issues surrounding the deployment of digital storytelling as instructional technology in the classroom.

What Is a Story?

Stories matter. Whenever we create, listen, view or retell stories, we access key and distinctly human ways in which we inherit our knowledge and values (Eisvaran 2013). We also expand and transform who we are (Tendero 2006), describe, define, and analyze what we do (Kress 2003), and formulate what we can experience and understand about ourselves and others (Jewitt 2002; Turkle 2011). Yet, given their antecedents in language, society and culture, stories and storytellers are

never innocent. Further, storytelling epistemologically, ontologically, and morally is rarely disinterested or neutral. There is always a point to a story but who gets to tell or create one depends largely on who they are, where they are from, what the story is about, and where it might lead us. Indeed, even what counts in a story is moot. This is particularly true in the combined case of education and the use of digital technology as we illustrate shortly.

Storytelling in education (language arts, especially) is longstanding (Morgan and Rinvolutri 1983) but the recruitment of technology enabling learners either working individually or collectively to combine text, sounds, music, images, gestures, and movement in their stories is a relatively recent curriculum innovation in most school-based subjects. Essentially, the rationale and impetus for Digital Storytelling (DST) is expansive, all-inclusive (Ohler 2008), and necessarily distinctive (Hull 2003; Hull and Nelson 2005; Jenkins and Lonsdale 2007) largely due to our particular understanding and biases concerning what counts as knowledge and how it is manifested in particular disciplines and subject areas for specific instructional purposes. These are fundamentally pedagogical issues.

According Morgan and Rinvolutri (1983, p. 9) “[s]tories are everywhere,” but behind their ubiquity lies a complex – and often unquestioned or unexamined – web of characteristics, purposes, and social investments. As a type of text, a story may be a factual or fictional recount of events, an incident, a statement of facts relating to a particular situation, a rumor, a lie, or a testimony, and so on. Stories can be, for example, fun, serious, frivolous, political, judgmental, controversial, and dangerous (Ohler 2008) in the sense that we can be “taken in” by them and their portrayals for better or worse. Stories, then, are never innocent or unconcerned and their impact or influence depends on several factors relating to storytelling. Three of these include structure, purposes, and the delivery. In terms of their multivariate structures, storytellers, especially in narratives and certain types of novel, characteristically have a plan or a plot in mind. Stereotypically, this might involve action involving a quest, conflict-resolution, or in

the case of the *bildungsroman*, character formation or coming-of-age. In addition, opportunities, challenges, and goals presented to central characters and events often involve conflict, growth, and climaxes which result in transformations from humble beginnings, to complicated middles and unexpected (but happy) endings. For instance, we often view the trials and tribulations of the reluctant hero or the nascent genius as particularly intriguing, thought-provoking, and entertaining. We might even wonder, when the structure of a story is “good,” what we might have done or thought in a similar situation to that of a favored protagonist.

We note that some but not all stories in their apparently wide-ranging variation, nonetheless following particular logics: the hero gets the girl, they live happily ever after, the villain is killed, and so on. As a consequence, we often are taken aback and follow along in rapt attention to stories that present dramatic deviations from well-worn narratives. Either that, or we perceive something to be “off” about a story with an unconventional narrative. Whatever the case, these stories are not merely entertainment; they are acts of communication and rely upon (and communicate) societal expectations of what constitutes orderly, sensible, and reasonable trajectories of human behavior, even if the stories are not about them. The story of the Garden of Eden, or any creation mythology, for instance, is decidedly not an innocent story about the happenings of a time past – it presents itself as an explanation for why the world is as it is and how we ought to live.

The centrality of narrative to our understanding of our life trajectories has also been a core principle for a form of qualitative investigation (Clandinin and Connelly 2000; Conle 2000; Polkinghorne 1988; Smith 2007). From this perspective, humans interpret meaning to the apparently random string of events that occur in their lives by fitting them into narrative sequences that make sense. We are literally the authors of our own stories, interpreting new events within the logic of the narratives to date, and reacting to conserve the storyline and identities of who we think we are in our stories – hero, victim, bystander, and so on. Such an approach gives a

significant ethical purpose to broadening students’ repertoire of possible story lines; for instance, it would be hard for a student to understand other ethnicities if she were surrounded by dehumanizing narratives. Indeed, it has been observed that a common precursor of genocide has been the promulgation of dehumanizing narratives by state agencies (Edward Day and Vandiver 2000; Neilsen 2015). An educative approach could help students appreciate that a particular narrative “does not have to end this way,” that alternatives exist to the currently acceptable way of seeing things.

If we were to apply Bakhtin’s (1986) theory of speech genres to stories, then each and every story told would be considered a string of utterances (where an utterance is a unit of meaning in a chain of others’ utterances that precede and follow it) sited within a broad social, historical, and dialogized framework of communication. As Bakhtin (1986, p. 95) states, “An essential (constitutive) marker of the utterance is its quality of being directed to someone, its *addressivity* (emphasis in the original).” An addressee can be an immediate participant-interlocutor or a more distant “audience” in time and space. Thus, with each telling or retelling of a story over moments in time, a new link in that particular story’s chain of utterances is added and fused to it. Furthermore, and vitally importantly, as a story’s chain of utterances extends and the circle of addressees expands, we create new meanings that are located in particular time/space configurations. Thus the meanings of stories – even though authorial intention is important – are always shifting, developing, and reliant on the contexts and social situations in which they are embedded.

Even ostensibly “identical” stories take on different meanings – the same creation myth justified the oppression of women, and explained the problem of evil. We interpret the random flow of events in our lives in terms of narratives that give it structure; things happen for a reason, and we proceed to act in particular ways because the way the tea leaves fall compels us to.

More generally speaking, stories do not always need to offer explicit ethico-moral messages of

purpose, but rather, within the constraints of the way in which stories are structured, and made intelligible to audiences, need to be thought of as a meaningful interaction between the author's intent and the cultural norms of the addressee community. Indeed, as far as fidelity goes, not everything a storyteller intends is always conveyed as planned; our meanings can be difficult to discern, at times due to the contingencies of time, space, and context. For example, the "same" story told in a men's locker room is potentially related but not identical to a similar recount of a particular set of events at a wedding party or an after-dinner chat.

If we accept these points of view, then storytellers stand in a special relationship to the stories they tell. Put briefly, even when the content of a story may not coincide personally, storytellers are, nonetheless, by virtue of their enactment, an essential part of the stories they tell. In fact, when a story is told (even one that is familiar) we often learn something of the storyteller in relation to what he or she may think, feel, know, or value at a specific point and time. We can also claim the same idea for the stories we hear and watch.

In summary, while stories may be commonplace and involve the telling of events or the conveyance of knowledge and information in recognizable and accepted formats, they are neither static nor impersonal entities. Rather, the components of a story involve both the story and the teller, and this, we contend, plays a major part in understanding what a story is about, its importance, purposes, and implications. These points relate to stories and storytelling in education as much as they do to novels, histories and jokes, etc. Stories are always invested, never impartial, and characteristically have a series of points to make in particular ways about who we are, and what we believe and value. It is the peculiarly contextualized nature of values that make an education in stories an important one. Simply knowing a limited set of stories, one type of narrative, provides for an unnecessarily narrowed version of purposes, intents, and relationships. Learning to tell stories provides one with opportunities to ponder about the relative valuing of particular courses of

action, their ethical appropriateness, and their aesthetic value.

Values and Education

It should not be too surprising that the language arts and the humanities appear to be natural venues for value education (for instance, in school subjects such as citizenship and moral education). The apparent appropriateness of stories for communicating certain types of knowledge hints at underlying structural differences between different forms of knowledge. At least the prominent sociologist of education Basil Bernstein (1977, 2003) has noticed that a distinction, quite coarsely, between what he termed as horizontal and vertical knowledge. Verticality refers to the capacity of a knowledge form to build "upwards" as in a form of accretion—for instance, knowledge in the natural sciences tends to be built upon prior findings. On the other hand, horizontal knowledge tends to develop via a radical break from prior traditions—Bernstein used the example of knowledge in sociology, where multiple interpretations of the same phenomenon (the nature of social reality) was more likely than in the natural sciences. Without going too far into what may essentially be the problem of demarcation (Pigliucci and Boudry 2013; Popper 1999), it is nonetheless pertinent to note that significant enough differences exist such that it is important for educators to have an understanding of these issues that can influence the way we design and communicate these types of knowledge to students. For instance, if we understand sociological knowledge to be largely a matter of interpretation, and that what is deemed to be correct a matter of social convention and always up for contention (a corollary of the horizontal characterization), then it is possible that what is known becomes less important than the kind of knower that we desire our learners to be. Indeed, much of Bernstein's work has focused on the social consequences of the differential distribution of high-status knowledge, which necessarily requires researchers to come to terms with the nature of these types of knowledge in themselves.

When we teach students to tell stories, we need to acknowledge the form of the pedagogical intent – not of necessarily communicating particular knowledge claims about empirical phenomena, but more of causing someone else to become a particular kind of knower, placed in particular relationships with the phenomena at hand. While the technical aspects of storytelling can appear prominent, especially since assessment of technique can be perceived to be more ‘objective,’ it is rather our contention that knower relationships with truth claims are currently under-developed and require more attention in schools. This is not to say that there is a shortage of research, as we will discuss in the next section.

It should be obvious here that differential distribution of power involved in the teacher student relationship will have significant influence on the result of this pedagogical interaction. What the teacher believes to count as a legitimate story or story components can have an outsize influence on the eventual learning outcomes of the activity. For instance, Towndrow, Nelson and Wan Fareed (2013) relate the school assessment experiences of Jeremy, a Singaporean schoolboy who created a digital story about his mother’s life of growing up on a public housing estate. In terms of draftsmanship, his hand-drawn scanned images were deliberately sparse and non-naturalistic (e.g., stick figures and two-dimensional rectangular buildings) to convey and visually reinforce the nostalgic-reflective theme of a particular childhood from a young person’s perspective. Jeremy’s teacher did not recognize these features of the story’s design and marked him only averagely according to a standardizing rubric under the category of “ICT usage – Images and Sound Track.” Apparently, his “artlessness” was misconstrued as a lack of ability and maturity. While we would not go so far as to say that we are left in a dilemma in a situation such as this, it is not hard to imagine a situation where we would be. It is quite clear here that the teacher failed to see Jeremy’s departure from aesthetic norms for its creative intent; yet, would it be hard to see another situation where a student “does not get it,” and what is really lost as a consequence?

If we consider a goal of education to be that of literacy, it can be conventionally understood that literacy entails a set of skills to master. Broadly, when we describe a person as literate, we tend to envisage someone who is educated, cultured or competent in a particular subject area or domain. The implication is that anyone who is unable to meet the standards – for whatever reason(s) – fails to meet what it takes to be a fully functioning member of society. There are others who have an even more encompassing and demanding viewpoint. For example, according to Freebody and Luke (2003, p. 53), literacy refers to “... the extent to which people and communities can take part, fluently, effectively and critically, in the various text- and discourse-based events that characterize contemporary semiotic societies and economies.” This is a complex, multifaceted and embedded phenomenon, as Freebody and Luke continue to explain (p. 53): to be literate is to be a participant in literate societies, which are, “... themselves composed of a vast range of sites, locations and events that entail print, visual and analogue media.”

Moving even more widely, Comber and Kamler (1997, p. 1) suggest that literacy is essentially socially constructed, and we can explicitly locate it in institutional contexts where its “... uses are never neutral or innocent, that the meanings constructed in text are ideological and involved in producing, re-producing and maintaining arrangements of power which are unequal.” Literacy, then, is something we create and is socially invested at multiple levels of interest for particular purposes that we define for different reasons. There is also a crucial sense in which contemporary literacy involves far more than the search for static meanings residing within written texts towards their active transformation via readers’ interactions, interpretations, and thinking (Hiebert 1991). Moreover, culturally appropriate ways of thinking have become important in developing literacy beyond focusing on reading or writing, *per se*.

And so, in order to help students develop relevant and meaningful literacy practices, teachers would need to understand numerous varieties of literacy thinking as manifested in different

subject-areas, societies, cultures, and environments (Langer 1991; Rassool 1999; Unsworth 2006). Thus, the forms, functions and uses of literacy are never free-standing, nonpluralist, or disinterested, a priori, by factors relating to the technologies of reading and writing alone (Dubin and Kuhlman 1992; Goody 1977). For example, under this vastly expanded purview, even learning to play a computer game might well be a literacy in its own right (Gee 2004).

The role of educators in these interactions needs careful balance between the poles of communicating canonical interpretations and supporting and developing students' perspectives. Here, it would be necessary to include more recent perspectives on the nature of knowledge and its role in society. For quite some time now, the recognition that horizontal knowledge forms are ruled by a certain sense of social convention, and hence arbitrariness, has not escaped advocates of social justice. Neatly encapsulated as a conflict between knowledge of the powerful and powerful knowledge (Maton and Moore 2010; Young 2008; Young and Muller 2007), earlier advocates believed that *all* knowledge was a matter of social convention, and that truth only existed because of power relationships which were often unfair. More recently, and in contrast to the above, scholars have been realizing that this position can be taken too far, and that there exists knowledge claims that, while ultimately based on social convention, are not completely arbitrary. In fact, and especially for knowledge claims in the natural sciences, the empirical nature of many knowledge claims produce obligatory boundaries to what may be socially constructed. Such was the conclusion of researchers such as Laudan (1996), and more recently Collins and Evans (2017), and Collins, Evans and Weinel (2017) – essentially, while we acknowledge scientific knowledge to be socially constructed, and that the practices of certain scientists to be less than exemplary, this should not cause us to detract from the ideal of the minimization of arbitrariness, or, in the worst excesses of the relativist line of thought, agree that the contemporary arguments against vaccination have equal merit to the scientific consensus on that issue.

The use of storytelling as a means to teach scientific and technical content has been deployed as a means to increase student engagement, or (better) as a means to emphasize the conflicts that often arise in the use of science and technology in societies. Here, educators can tread a fine line between either communicating the scientific knowledge too zealously, or overly problematizing knowledge claims. In either case, careful attention to the nature of knowledge claims is required by the educator.

New Media and Multimodality

Conventionally, new media encompasses the networked information and communication technologies that emerged in the late twentieth century. Nowadays, in contrast to longstanding one-to-many media platforms (e.g., radio, television, and newspapers), new media are typically the many-to-many social and widely distributed platforms we use for creating, sharing, discussing and modifying user-generated content. Jenkins et al. (2006) note how new digital technologies are changing the way young people learn, play, socialize, and participate in civil life. New media are also changing perceptions about individuals' identity and what they can potentially become – or not – through constant on-line connectivity (also see Dede 2005; Gee and Hayes 2011; Healy 1999; Postman 1993; Turkle 2011).

A central characteristic of the newness of new media is not necessarily associated with their novelty but lies rather in the empowerment that comes from making meaningful decisions (Jenkins et al. 2006) and control-taking (Shapiro 1999). Indeed, some would contend that new media – through the central elements of globalization and active participation – allow individuals to personalize information by manipulating and overcoming the limits of time and space in hitherto unprecedented ways (Shapiro 1999).

By the mid-1990s, media and digital technology integration gave rise to views of literacy incorporating a multiplicity of semiotic elements for communication – meaning-making production and interpretation (cf. Cummins et al. 2007; Gee

2009; Warschauer 2006). For example, when reporting the design and meaning-making potential of multimodal authoring, Hull and Nelson (2005) show through fine-grained analysis how Randy, a Californian multimedia artist, combined poetry, photographs, images, jazz music, and rap into an autobiographical tapestry and social critique of life in the bay area of San Francisco.

Interestingly, while Hull and Nelson's (2005) research illustrates the communicative potential of multimodal composition by a minority youth member in a tough and challenging urban context, it is equally the case that new media authorship can be restricted and hindered by textual conventions and taken-for-granted categorizations. For example, writing within the field of learning English as a second language, Nelson (2005) shows how a Mandarin-speaking student named Bonnie became very self-conscious about what she thought her audience might expect to see in her multimedia-based story about living in three distinct countries. At one point, she chose an online image of a pagoda to illustrate the Taiwanese flavor of her previous cultural surroundings even though she knew from personal experience that this building was not as grandiose as it appeared in the shot she had chosen. Nelson goes on to suggest that the use of cultural and societal stereotypical representations may be an instance of an overaccommodation of audience expectations (in this case what others perceived to count as or represent Taiwanese-ness) and thus serve as self-imposed limitations on authorial voice and intention.

In sum, new media and changed personal situations (Birkerts 1994) profoundly challenge the long-established logics of literacy and teaching rooted in essayist (pen-and-paper) and print-based epistemic authority (c.f., Kramer-Dahl 2008; Kress 2007). Further, given its all-embracing nature and historical context, multimodality – as part of the larger multiliteracies agenda (New London Group 1996) – complicates traditional notions of authorship, meaning making, and authenticity. Indeed, for some, the established and (at times) unquestioned literacy practices and procedures of classrooms, and beyond, are proving to be inadequate and insufficient. They

not only disappoint young people whose expectations of engagement and interaction are greater and distinct (Brooks-Young 2010; Jukes et al. 2010; Prensky 2010; Ware 2008), but also suggest shortcomings in directing instructional and pedagogic momentum towards the development of the new domains of work, identity, changing subjectivities and citizenship required in the twenty-first Century (Ajayi 2009; Hull and Katz 2006; Ohler 2010; Lam 2006; Tapscott 2009).

Concluding Remarks

In sum, we believe our portrayal of the educative value of digital storytelling is neither absolute nor deterministic. Rather, we acknowledge and celebrate the potential that storytelling has to expand the boundaries of learning and instruction axiologically and agentially. Stories are not limited by content or subject area and do not only depend on learners' linguistic or aesthetic capabilities. We attribute these effects to a range of factors including the nature of different types of knowledge, the potentialities of new media and multimodal communication, and characteristic conjunctions between a story (structure and content) and storytelling (delivery). Overall, we contend that given the complexities of story creation and telling, stories can never be merely the linear sum of their parts.

While educative and synergistic gains are possible, there is an accompanying risk of stymying digital storytelling by limiting its scale and scope. For example, this may happen when digital storytelling is viewed as a largely technical enterprise where fidelity to accepted and common story structures (characterization, plot, and content) and prowess in using computers and software are valued higher than artistry and unconventionality. A related issue concerns maintaining an essayist's view of literacy relating to storytelling as ways of demonstrating linguistic and/or conceptual mastery.

It is pointless to deny or decry the instructional needs of formal education to teach and test learners. Yet, more broadly, as far as digital storytelling is concerned, we encourage educators

interested in this field to be clear – pedagogically, theoretically, ethically, and practically – about their decisions and choices in instructional design, and to become more aware of the trade-offs they may enter into and receive.

Cross-References

- [Digital Citizenship, A Sociocultural Snapshot](#)
- [Literacy and Technology](#)
- [Technology Enhanced Learning](#)

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Educators and Children Perceiving Affordances with Working Technologies in Early Childhood Settings

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Synonyms

Cameras; Computers; Early childhood; ICT; iPads; Play

Introduction

The range of digital technologies available in early childhood education (ECE) settings for children birth to 5 years has increased over the last decade. While somewhat limited literature exists across the ECE field, researchers have now begun to explore how children engage with technologies, rather than concentrate solely on the quantifying screen time exposure and impacts (Bird and Edwards 2015; Marsh et al. 2016). More

specifically exploring how young children engage with provided technologies provided in ECE settings will increase the practitioner's knowledge base and effectively promote children's learning with technology devices. The types of technologies provided for children's use are detailed below, along with professional learning, the perceived affordances with devices, how children respond to provided technologies, and a discussion on the effect of changing perceived affordances.

Working Technologies Provided and How They Are Used

Within early childhood centers, both imaginative and working technologies can be offered. Imaginative technologies are those provided in pretend dramatic play spaces, possibly arranged as home corners, doctor surgeries, hospitals, or restaurants (Bird 2019). In contrast, working technologies include iPads and tablets, still and video cameras, interactive whiteboards, robotics, and coding devices (Bird 2017). With the introduction of the iPad in 2010, ECE settings have embraced these devices for their ease and usability with young children. They are often provided for children's free play, but as yet limited to no adequate support is offered to educators to integrate them successfully within their programs and pedagogies.

While technologies have been associated with negative impacts on young children's health and well-being, recent researchers have called for more comprehensive exploration into how the devices are being used. For example, active participation requires children to design and create their digital experiences rather than be "passive responders" to screens and media (O'Mara and Laidlaw 2011, p. 152). In her doctoral research, Scott (2018) found that children's engagement with television and related media extended beyond just viewing the screen and absorbing what was being fed to them. Instead, the children danced, sang, and took the themes from media and embedded them into their play. Children adopt their play themes from their everyday experiences, and in the digital age, this includes

technologies and related media. Children also reenact the experiences from their communities as they practice behaviors and act out societal roles that may one day be integral to their futures. Again, these will likely involve technologies and associated digital literacies.

Providing working technologies in ECE settings reflects wider society's uptake of technologies and potentially builds digital literacy links between home and early childhood contexts. Children may be supported to use technologies at home and experience a wider range of devices and practices than those typically incorporated in ECE programs. Children may attend their ECE settings with significant experiential knowledge around technologies and expect to encounter these technologies in their daily learning. However, they may find their ECE setting is void of any devices and play involving technologies is actively discouraged by educators.

Educators' Provision of Digital Technologies

Many studies have explored the reasons for educators' reluctance to provide technologies in ECE settings. The reasons cited have ranged from limited educator confidence, to lack of hardware and devices, scant pedagogical understandings of technologies, to somewhat narrow beliefs about the role of technologies in young children's education. As Blackwell et al. (2014) report, educators did not grow up with technologies, so often they do not feel comfortable or confident in sharing technologies with the children they teach. This is slowly shifting. As technologies are increasingly embedded in our daily lives, educators are becoming more digitally literate, such as confidently using devices in their personal lives. The issue is then to transfer their personal skills around technology into their personal lives and into their professional lives in a way that transforms their pedagogical understandings and improves their technology provisions for children.

One contributory factor to increase technology provision in ECE settings is to offer technology-targeted professional learning. Unfortunately,

such professional learning does not always meet educators' needs or reflect the different devices or the cultures represented in the various centers. How this can be achieved is still an area of ongoing investigation. Either way, technologies are an integral part of children's realities and their daily lives, and they employ these digital experiences in their imaginative play scenarios. Therefore, ECE settings must reflect these experiences and support children's understandings of their social contexts including digital literacies.

In exploring how children engage in imaginative play using working technologies, Bird (2017) created new challenges as there are many elements that need to be in place before the technology will allow children to engage in the type of play that educators recognize and value as contributing to learning. Alongside this issue is the provision of these devices and the rules and restrictions educators apply to their use and how they impact children's imaginative play. In the following sections, the affordances of the provided technologies will be discussed from both the children's and the educators' perspectives. Also discussed are the effects the perceived affordances have on children's play and learning and the rules and restrictions educators place on the device usage.

The Perceived Affordances of the Provided Technologies

Gibson (1979) explained the concept of affordance as relating to the individual perceiving the affordance. First, the individual must perceive an affordance in order for it to be recognized. The perceived affordance is determined by the individual through environmental stimulus information. In relation to children's technology use, stimulus information may include the availability of the devices, the rules and restrictions that may influence usage, and also the child's prior device knowledge or skills.

Increasingly in ECE settings, devices or working technologies are provided and promote affordance. The devices might include computers, iPads and tablets, cameras both video and still,

and digitally enhanced toys. How the devices are employed ranges from educators using iPads to research current topics of interest or to play songs to children being allowed free access to iPads to play and take photos.

Children's Response to Provided Technologies

Children appear to respond to the technologies in three ways. The first is to *accept* the technology as provided; the second is to *negotiate* the rules and restrictions applied to the technology in order to play in the way they choose; and the third is to *abandon* their playful plans. When children *accept* the technologies, and use them in their play, they perceive the affordance of the technology to play imaginatively. Often educators apply rules and restrictions around children's use of technologies and children perceive affordances with the technologies, but at times children need to *negotiate* the rules before their imaginative play can be realized. For example, children might attempt to negotiate a time restriction and remain at a device even after the timer has expired. Another restriction might be that children are not allowed to stand behind a device and watch another child having a turn. Children have been observed to negotiate this by remaining in situ after their turn has finished. If the children are not successful in *negotiating* the rules and restrictions placed on devices, they typically *abandon* their play.

For children to perceive affordances with devices, other "mini or aligned" affordances are required to be in place before the main affordance can be perceived. This is similar to executing a planned affordance. For example, airport baggage screening processes actually incorporate many affordances that need to align to promote passenger safety (Pols 2012). In the same way, children's use of working technologies needs many affordances to align for the children to be able to play imaginatively and fully explore digital literacies through play.

Further, children and educators perceive the working technology affordances differently.

Children perceive that the working technologies can afford them imaginative play and display this through their *acceptance* and *negotiation* of the rules and restrictions associated with each device. Interestingly, educators do not perceive that technologies can afford imaginative play, often displayed in their lack of direct engagement with children around technology play. I argue this is a key concern, as educators seem to be missing important learning opportunities through their lack of direct engagement with children as they playfully interact with working technologies. Research by Furman et al. (2018) found that children's learning increased when educators interacted and supported learning on these devices. The first step in executing a planned affordance is for educators to recognize the potential affordances of working technologies for children's learning, the second is that educators need the pedagogical skills to support the learning potential, and then, finally the time required to ensure interactions occur to promote learning.

A Change to Perceptions

If the educators perceived the affordances for the children's imaginative play, their pedagogical strategies would support and encourage children's engagement with the technologies. Instead, a tension appears between the children's perceptions of the technological affordances and the educators' lack of perceived affordances. This tension also highlights a difference between the working and the imaginative technologies (Bird 2019). In Bird's study, educators identified play with imaginative technologies as corresponding with their personal definition and beliefs about "real play," and therefore they knew how to pedagogically scaffold the play. When asked how they supported and extended children's working technology play, educators often did not know or referred to the technical assistance they provided in making the device work efficiently.

Technologies are often viewed differently to other activities in ECE settings. When children are engaged in collage or construction activities, educators do not monitor the time being spent

there. In contrast, timers are often used to control the time children spend on working technologies. The covert message received by the children is their technology involvement is not as valued as other activities. Children see the computer and iPad and what they can afford "as important to their play and learning" (Bird 2017, p. 110), but in contrast, educators can see them as a special treat to be utilized on rainy days. This difference in perception results in rules and restrictions around their provision that constrains the children's abilities to engage in imaginative play with the various technologies on offer. The educators' views about technological affordance are in opposition to the long-held belief that play is the vehicle for children's learning in ECE settings. Instead, if educators viewed children's engagement with technologies as play, they would actively scaffold the play, just as they do around play with imaginative technologies. As acknowledged in recent research, educator involvement around technologies is not only required to develop children's skills with device functions (Bird and Edwards 2015) but also to build conceptual knowledges and extend children's understandings about what is occurring on the screen (Reid-chassiakos et al. 2016).

Another area of concern is the often underrepresented observations and assessment of children's learning and development in educators' documentation of children's engagement with the technologies. Educators describe not understanding or feeling confident with what children actually "do" with technologies, and therefore observations tend to be statements of children using technologies, rather than what they are learning or the skills they might be developing. This concern aligns with two points established in current literature. The first is that educators do not fully understand children's engagement with technologies and what they could possibly be learning, and, secondly, educators lack confidence in recognizing traditional forms of play in children's technological practices (Bird 2019). When educators witness children's technological play, they do not always observe what is actually happening on devices, a critical requirement to recognize play. With technologies increasing in both society and

ECE settings, building educator understandings of how children play and learn with technologies is vitally important. In addition, educators need appropriate pedagogical knowledge to scaffold children's play and learning and to extend possibilities for learning.

Technologies must be seen as integrated into the ECE curriculum, embedded into a range, if not all, activities both indoors and outdoors. In building educator knowledge around ways to support children's play and learning with technologies, the focus needs to shift from "how can I provide this technology" to "how can I actively engage in the activity being provided to scaffold children's play and learning with technologies?" Shifting the educator's focus from the technology alone to either the children's play and learning or to the aims of an activity more effectively builds children's understandings that technologies are one of many useful tools to achieve a specific task. This also strengthens educators' pedagogical knowledge for embedding technologies in all areas of their programs.

Children and educators perceive affordances with technologies differently, and this can be viewed as a continuum. At one end, children perceive the technologies affording them imaginative play, whereas the educators are positioned at the other end of the scale and do not see the same affordance possibilities. The children "were advancing in-step with society's technological understandings and the educators remained stuck in their traditional beliefs and practices of a time when digital technologies were not so prevalent" (Bird 2017, p. 110). The goal of technology provision is to bring the educators' perception of technology affordances for imaginative play into line with how the children perceive them. As previously stated, educators use technologies in their personal lives (Lafton 2015), and what is needed is to encourage them to transfer this knowledge into their professional lives with children.

Conclusion

It is clear that children and educators perceive the affordances of technologies in imaginative play

differently. The barriers to educators' provision can be addressed through research around how children engage with technologies in their imaginative play. Such research findings can be disseminated to educators in ways that increase educator's knowledge and assist them with rethinking their technology-related, pedagogical beliefs.

As discussed at the outset, the research focus needs to shift from children's amount of screen time to the type of activities being undertaken with technological devices. By making this shift, children and educators can focus on technologies being a tool to assist with various activities and learning outcomes, rather than an activity of itself. Changing the focus will assist with embedding technologies into ECE programs and exposing children to appropriate uses of technologies. Discussed in the literature is the notion that children play to practice community behaviors and enact future roles, and by successfully embedding technologies into all areas of early childhood programs, children can practice these behaviors and work toward becoming effective and responsible digital citizens.

Cross-References

- [Adoption of Innovative ICT-enabled Systems for Analysis- and Intuition-styled Teachers in Primary Schools](#)
- [Computers and Educational Improvement](#)
- [Computers in Primary Schools, Educational Games](#)
- [Teaching with Computing, Educational Games](#)

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Edutainment

- ▶ [Computers in Primary Schools, Educational Games](#)
- ▶ [Game-Based Learning](#)
- ▶ [Gamification](#)

eExams

- ▶ [Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption](#)

E-Learning

- ▶ [Art Component of Remote Training in Russian Universities](#)
- ▶ [Computers and Educational Improvement](#)
- ▶ [Flexible and Distance Learning](#)
- ▶ [IT on Teaching and Learning Process of Visually Impaired Students](#)
- ▶ [Learning Management Systems, An Overview](#)
- ▶ [Mobile Learning, Challenges in](#)
- ▶ [Technology-Enhanced Learning](#)

eLearning in Saudi Arabian Universities, Toward Blended Learning

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Synonyms

[Blended learning](#); [Hybrid learning](#); [Integrated learning instructor](#); [Lecturer](#); [Teacher](#)

Introduction

This entry discusses the Kingdom of Saudi Arabia (KSA), a country with an immense natural resource of oil, the production and sale of which underpins the economy of the country. The country has a rapidly growing population that in 2018 was over 33 million, of which 58% were below the age of 34 years. One consequence of such rapid population growth is that colleges and universities within the country have been confronted with two challenges during the current century: to improve the quality of education and to make higher education available to a vast and increasing number of students.

There have been some key emergent issues in that scenario that initially led the Ministry of

Education to permit universities to develop wholly online degree programs. First, the physical size of the country makes it difficult for all potential students to attend university campuses, especially women who were typically reliant on male relatives or hired drivers to transport them. Second, the national social mores did not allow for coeducational learning, leading to the development of segregated gender provision. More importantly, however, was that there was limited capacity within Saudi public universities to cater for those who are entitled to study in higher education. This led the Ministry of Higher Education to identify online provision as one possible answer to these challenges and to establish the National Centre of Electronic and Distance Learning (NCEL) in 2006 to create and categorize change in respect to eLearning and distance learning materials. Subsequently many universities began creating wholly online degree programs, supported by government funding, to the extent that 15 out of 25 public Saudi universities were offering such programs by 2013. By 2014, the number of students enrolled on wholly online programs reached 350,000, which constituted 33% of higher education students at Saudi universities, with more students enrolled on such courses than those receiving traditional instruction.

Students who graduated from such programs suffered, however, from the degrees not being accepted as valid in some private sector companies, for teaching in schools with other Arab countries in the Middle East or even progressing to postgraduate study (Ministry of Education 2014). In addition, online degree programs were considered to have challenges which disaffected learners and had often proved unpopular in KSA with most students lacking the requisite skills to make use of such learning methods (Al-Mousa 2004).

In 2014 the Ministry of Education (MOE) published a commissioned report which questioned the value of wholly online programs and concluded that such provision in the kingdom was effectively out of control and had become disconnected from the needs of the labor market (Ministry of Education 2014). As a learning

method and component of the Saudi education system, wholly online learning was considered as no longer fit for purpose, with one study revealing that instructors themselves had little faith in the quality of their own institution's online programs (Al-Draiby 2010). Furthermore, employers (including the government itself) were placing a low value on the qualifications emerging from this provision and a lack of regulation and quality control.

The ultimate outcome of this investigation was that universities were advised by Deputy Minister for Education Affairs not to accept any further students in eLearning courses for the academic year of 2016–17. Instead, the Saudi Electronic University (SEU), the first electronic university in the Arab world and which had been established in 2012 to offer specific prerequisite courses as demanded by the labor market, was to develop “centers for eLearning” throughout the country with the assistance of other universities. Central to this planned provision was blended learning (BL), a combination of face-to-face (f2f) and distance online learning (DL).

The Case for Blended Learning (BL)

A wide range of advantages have been ascribed to BL which is seen as advantageous in comparison to wholly online or traditional face-to-face methods. BL is considered as offering enhanced instructor–learner and learner–learner interaction which includes personalized, timely, and iterative feedback (Hrastinski 2008). BL also avoids the pitfall of DL's potential to become the ultimate in didactic learning with information simply dumped on learners via the World Wide Web (Garrison and Kanuka 2004). With a significant face-to-face component, BL learners are less likely to experience the detachment, demotivation, and distraction associated with wholly online degree programs (Galusha 2011). Instead, BL offers flexible interactions and opportunity for knowledge coproduction (Vaughan 2014).

Additional advantages over face-to-face-only methods mainly concern access and cost as BL

can channel higher education to parts of a population that were previously problematic, including mature students already in employment or those with family responsibilities which makes full-time attendance difficult, so extending the geographic reach. In Saudi Arabia, BL also creates practical possibilities to overcome social and cultural barriers to male–female interactions. A female student can attend and participate in a virtual class with male instructors and fellow students, for example, in a way that would not occur in a physical classroom. On a theoretical level, BL also fits with a constructivist and co-constructivist approach to learning mainly through its ability to facilitate collaborative tasks (Stahl et al. 2006).

Overall, given the problems emerging from the rapid expansion of online degree programs in the kingdom, it is unsurprising that policy makers viewed BL as a viable new path to achieving their objectives. When combined with appropriate quality control BL was considered to offer the Saudi HE system a realistic path to achieving the country's goals. A major element of this quality control was to bring all BL provision under the control of one institution – the Saudi Electronic University (SEU). For the 2016–2017 academic year, public universities were thus instructed by the MOE to cease enrolling new students for their online degree programs.

The SEU Plan

The SEU was already operating at the time the government withdrew its support for eLearning programs that were running in most Saudi public universities. It was established by royal decree signed on September 7, 2011, and rather than delivering programs entirely online the university was to facilitate BL, with three-quarters of course content being online and the other quarter being delivered face-to-face. The royal decree was accompanied by a statement from the MOE that explained that the new public university would provide higher education and lifelong learning with undergraduate, postgraduate, and continuous learning programs under the

supervision of the Higher Education Council (Ministry of Education 2015). On opening the SEU would have three colleges, Administrative, and Financial Sciences, Computing, and Informatics, and Health Sciences. Subsequently, a fourth college, Science and Theoretical Studies, was opened. In addition to the main Riyadh campus, three branches were opened in 2012 in Jeddah, Dammam, and Madinah. On opening the SEU the Director announced that 60% of places at the new university would be reserved for female students. At the time of its launch, the strategic plan was to open 20 branches across the KSA and serve up to 100,000 students in 10 years' time. The SEU divided most of its campuses into male and female locations, employing female instructors for female learners. For the online component, female learners could interact with male instructors and students, as educational segregation does not extend to the Internet.

Such an approach to student learning appears therefore to be sympathetic to the cultural norms traditionally associated with higher education in Saudi Arabia in that it is based on a relationship between instructor and student, thus allowing for a requisite amount of F2F interaction. In this way the SEU strategy seeks to address the potential issues of isolation and alienation found within previous research studies undertaken in the country. In addition, core aspects of the teaching programs were to be “live,” rather than asynchronous, to encourage the sense of student community that can evolve in learning cohorts.

Instruction and course materials were to be exclusively in the English language, a decision which brought the perceived benefit of being able to partner with global leaders in online learning provision such as Franklin University in the USA and the virtual learning environment, Blackboard Learn. These and other providers enabled the SEU to offer a wide range of undergraduate and postgraduate programs designed to an international standard. With such international partners in support, the SEU was expected to be able to deliver successfully a wide range of undergraduate courses and a postgraduate MBA. The use of English only would, subsequently, have more negative consequences in student retention,

however, an issue which will be examined in more detail below.

Admission to the SEU requires a secondary school certificate or equivalent though grades are considered the exact requirement is not published. Unlike traditional Saudi universities and as part of the commitment to lifelong learning there is no stipulation for the recency of the secondary qualification. Once admitted, SEU undergraduates follow a common preparatory year comprising English language, computing, communication skills, basic mathematics, and academic skills. Uniquely among Saudi public universities, students could continue to be employed while studying at the SEU.

The Early Years of the SEU

By the academic year 2016–2017, student numbers at the SEU had grown to 14,485 studying at one of eleven campuses, but this represented a slight fall on the previous academic year which suggested the planned trajectory toward 100,000 students was overly optimistic. The main reason for this can be seen in data publicly released by the SEU which reveal that only a small proportion of students in the common preparatory year progress onto their major degree pathway either because they do not pass the requirements for English (or other components of the first year) or because they drop out for other nonacademic reasons (SEU 2018). In the 2015–2016 academic year there were 10,233 students following the preparatory program and 4,844 in other years following their major or undertaking postgraduate studies, meaning that most students enrolled at the SEU were in their first year. In normal circumstances with so many students poised to commence their major degree program in 2016–2017, a huge rise in student numbers taking their major degree pathway would be expected. Instead, major student numbers fell back to 4,153. Allowing for some graduations, it appears that a negligible proportion of preparatory year students were progressing (SEU 2018).

The SEU was established to widen access to HE to mature students who had already embarked on their career or who had existing family responsibilities. The entry criteria are purposely set at a low level on the basis that a mandatory preparatory year could bring them to a satisfactory level in the skills they will need to complete their major degree pathway. From the university's data it appears, however, that all too often this does not happen (SEU 2018). It is recognized that attrition through changes in life circumstances may be unavoidable with an SEU student who is likely to be older, already be employed or already have family responsibilities. A change in job, a pregnancy, getting married, and moving home are all potential causes for withdrawing from a study program. In addition to this, Saudi HE, in general, has a problem with student retention and low graduation rates. Aljohani (2016), for example, analyzed institutional data and concluded that the average graduation rate for Saudis on 4-year program was 65% and falling to between 35% and 50% for those on 2-year programs.

Clearly, student retention is an issue in Saudi HE. In comparison in the UK only 6.4% of first-year undergraduates failed to progress to the second year of their studies in the academic year 2015–16 (HESA 2017). The rate of student attrition at SEU is high and thus a threat to the ambitions declared at its launch. The lack of an English language admission criterion would seem the most plausible explanation with many students unable to reach the required level by the end of the preparatory year, a level that is equivalent to an IELTS score of 5.5. At Saudi Arabia's traditional public universities, there is usually a requirement to hold a recent English proficiency certificate of between IELTS 5.0 and 6.0 before commencing the preparatory year.

There are also issues related to the stated objective of reserving 60% of its places for female students, with current data showing that only 35% of its students are female (SEU 2018). The reason for this divergent outcome can only be speculated on, as no study has been conducted. However, at

the 2015 International Conference on eLearning and DL held in Riyadh the Saudi Deputy Minister for Education Affairs, Al Ouhali, reported that across all eLearning in the kingdom two-thirds of learners were male, meaning the SEU outcome seems to be in line with the previous DL balance (Ministry of Education 2015).

The Challenges of BL at SEU

Following a BL program requires greater self-direction than one using traditional f2f methods and this raised the issue of a conflict between BL and Saudi cultural norms. Smith and Abouammoh (2013) explain that the rote learning of information by passive learners is a fundamental element of Saudi culture and religious teachings, as are structured lifestyles and work environments. This would suggest that self-direction may be challenging for some Saudi learners.

While the lack of English language skills has been given as the prime reason for low student retention rates in their first year, individual capability with the use of information technology is also a key component of the preparatory year and some students without a background of such skills appear to find this challenging. The decision to deliver all programs in English had the benefit of SEU being able to draw on the tried and tested technologies and practices of a range of global leading providers, enabling the university to populate its programs with content quickly and draw on non-Saudi instructors and instructor training services. It immediately exposed the university to certain risks, however, that appear to have called its ambitious development plans into question. On the one hand, it vowed to broaden access to higher education, while on the other hand delivering courses in English is restricting success only to those with a high level of English proficiency. Having a high proportion of preparatory year students failing to commence their major degree program in their second year is an inefficient use of resources, not to mention a discouraging experience for the students themselves.

Lessons from the SEU Experience

Improving English language instruction to get more students over that hurdle is one option. From the outset SEU has partnered with its global providers and SEU students have access to their online English school English Live. However, it seems that achieving a substantial increase in proficiency in just one academic year is beyond many students. Another option is to introduce a proficiency requirement at the point of enrolment for the preparatory year. With a common understanding that it takes 1 year to improve IELTS by a score of one point, it would seem necessary to have a higher requirement for IELTS first enrolling. While this would exclude many such a requirement would be likely to improve progress to their major degree program.

A further option that could help the SEU achieve its access goals would be to deliver some programs in Arabic. While Saudi Arabia's longer-term ambition (Vision 2030) is to develop an outward looking country with a diversified economy, some parts of that economy are never likely to need English language skills including those delivering services to the local population. The challenge here would be one of capacity to design and populate such programs as their international partners would probably not be able to help.

Concluding Thoughts

The establishment of SEU was a bold initiative initially designed to address the problems that had arisen with eLearning in the kingdom while taking advantage of the technological opportunities that are transforming learning around the world. A very early decision was taken to adopt BL as the preferred model of student learning, and while it is true that initial plans have failed to materialize as hoped, it remains a viable ambition for the Saudi HE system.

The key issues to address do not include the concept of blended learning as the arguments for

its adoption can be deemed to be secure. SEU, instead, will need to explore how to deal with admission requirements, which language to use for the degree programs, how to improve retention (which may be connected to the first two issues), and why the proportion of female students remains at similar levels to those witnessed on the previous wholly online programs.

Cross-References

- [Lifelong Learning for Working People](#)
- [Online Learning](#)

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Empowerment and Disempowerment in Peer Observation Within Pre-service Teacher, Technology-Assisted Integrated STEM Education

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Introduction

STEM education has been receiving increasing attention over recent years. It is seen to offer the potential to enhance development of various “soft” skills”; sometimes known as twenty-first century skills (Cronin 1996). These skills include, but are not limited to, creativity, innovation, critical thinking, decision-making, problem-solving, metacognition, collaboration, and communication.

STEM education is claimed to present a solution to preparing young people for jobs of the future. The Chief Scientist’s Office of Australia reports that there is a growing demand for STEM qualified employees (Prinsely and Barayai 2015).

Additionally, STEM education is seen as a potential approach to reversing high levels of disengagement with science and mathematics. Disengagement with these areas is reported to begin in primary school (Sullivan et al. 2006; Martin et al. 2012).

With the promise of STEM education as a rationale, academics within the University of Melbourne, Melbourne Graduate School of Education, working alongside academics and scientists from the Faculty of Science, the Gene Technology Access Centre (GTAC), the Victorian Space Science Education Centre (VSSEC), and the Melbourne Museum, have planned and facilitated an elective subject with preservice teacher education students (PSTs) with an integrated approach to STEM education as a focus. The facilitation of the elective subject has been funded through the Reconceptualising Maths and Science Teacher Education Programs (ReMSTEP); an Australian

Government program funded through the Office for Learning and Teaching (OLT).

Throughout the 3 years the elective subject operated, academics teaching in this elective were interested in helping students to develop Professional Learning Communities (PLCs) to support their STEM planning and teaching. The context of the subject seemed ideally suited to the facilitation of PLCs given that teams of PSTs collaboratively taught each classroom of school children. A key component of the PLCs developed in this subject was the opportunity for students to observe each other teach and provide peer feedback. While observing each other teach, pre-service teachers (PSTs) used their personal mobile devices to record observations on “Padlet (www.padlet.com)”; a digital media board that enabled individuals to express their thoughts on a common topic through real-time, text responses.

These responses were coded and analyzed to explore the types of feedback PSTs provided to each other. This supported the development of an understanding of where, based on learning areas, and how, based on the language used, PSTs directed their peer feedback when working in PLCs.

This analysis also explored the implications and evidence of power relationships between PSTs, who might be assumed to identify as holding similar levels of influence and power as they all identified as learners in the Masters teaching preparation course.

Upon investigation of literature focused on the impact of peer-observations on learning, it has become clear that a challenge exists in the acts of peer observations. An imbalance in the power (Cronin 1996) exhibited and enacted by those observing has been raised as a critical constraint of this learning strategy.

Facilitators of learning have reported negative feelings that include feeling surveilled by those perceived as holding power over them (Shortland 2004). One outcome of this identified challenge is seen to be teachers resisting change as they face uncertainty when using new pedagogies in their classrooms. Teachers felt inhibited by the perceived power of the observer. In this study we aim to examine whether PSTs equally perceive this power imbalance. We hypothesized that, in

their role as learners within the context of their initial teacher education, the PSTs would value the experience of peer observation feedback differently.

One source of data utilized within this study was a series of three open-ended online surveys. These surveys provided insight into how PSTs viewed the process of engaging in PLCs and providing and receiving peer feedback.

We aim to address two research questions in this chapter:

1. How do PSTs perceive peer observation and feedback, when utilizing online mobile technologies?
2. How do PSTs focus their peer feedback when utilizing online mobile technologies?

In the following sections, we first provide some discussion of literature in the area of tertiary level peer learning and the use of online mobile technologies to facilitate Computer Supported Collaborative Learning (CSCL). Next, we will provide some discussion of the Context and Study Design. A discussion of the Results will then occur and lastly some Conclusions and Implications will be offered.

Literature Review

This literature review is divided into two subsections. The first subsection provides background and discussion of literature supporting the first research question, while also providing discussion of literature closely aligned with the second research question. Where possible, the literature selected is based within the context of research in tertiary settings.

Peer Observation, Peer Learning, and Professional Learning Communities

While there is some variation in conceptions of what constitutes a PLC, Stoll et al. (2006, p. 223) state that “there appears to be broad international consensus that it (PLCs) suggests a group of

people sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented, growth-promoting way” (Stoll et al. 2006). The establishment and facilitation of a PLC can take many forms. However, a common component of PLCs is peer learning, regularly including peer observation, and peer feedback. In the context of our study, peer observation and feedback was central to the development of PLCs.

“Reciprocal peer learning,” which includes “peer observation,” has been described as “mutually beneficial and involves the sharing of knowledge, ideas and experience between the participants. It can be described as a way of moving beyond independent to interdependent or mutual learning” (Boud et al. 2014, p. 3).

Martin and Double (1998) describe the benefits of this approach in staff professional development as follows:

- Improve and develop an understanding of personal approaches to curriculum delivery;
- Enhance and extend teaching techniques and styles of presentation through collaboration;
- Engage in and refine interpersonal skills through the exchange of insights relating to the review of a specific teaching performance;
- Expand personal skills of evaluation and self-appraisal;
- To develop and refine curriculum planning skills in collaboration with a colleague; and.
- Identify areas of subject understanding and teaching activity which have a particular merit or are in need of further development.

In the majority of literature exploring peer learning and peer observation, there is agreement that feedback and observation should occur in a nonjudgmental, objective, and supportive manner (Boud et al. 2014; Martin and Double 1998; Cosh 1999).

Critiques of the approach, however, contend that the goal of peer observation is easily subverted. Shortland (2004) utilizes Derridean Deconstruction (Derrida 2016) to gain insight into how university documentation relating to the peer observation process can highlight issues

of power imbalance between the observer and observees. Deconstruction is described by Chaffee (2009, p. 80) as “a way of rereading texts to uncover the silences in the history of philosophical and social thought and, as he (Derrida) acknowledges, to create silences of its own.” Shortland (2004) contends that the observer involuntarily is placed in a more powerful position than the observee. Additionally, she argues that peer observation is used, at times, as a method of surveillance and used to ensure compliance by figures of authority or management. She states, “discussions revealed some staff members completing observation documentation simply to comply with the managerial requirements to do so, having not actually undertaken the observation process. A mechanism by teaching staff to highlight their perceived needs whilst minimizing their workload or an opportunity for resistance whilst not misbehaving?” (Shortland 2004, p. 226).

With these critiques of peer observation in tertiary level education in mind, we aim to gain an understanding of PST perceptions of the process in our STEM education focused elective subject.

Mobile Technologies Enabling Computer Supported Collaborative Learning (CSCL)

While there is an increasing volume of literature addressing the use of mobile devices, typically mobile/smart phones, tablets, or in some cases lap tops, in teaching and learning contexts (Ciampa 2014; Ekanayake and Wishart 2015; Fougler et al. 2013), little research exists specifically investigating the use of internet connected mobile devices to engage in collaborative, observational, feedback of peers within teacher preparation courses.

Symons et al. (2016, p. 2) describe Computer Supported Collaborative Learning (CSCL) as taking “place via the vehicle of technology (computers, tablets, mobile phones etc.) typically linked via an intranet or the internet.” Dillenbourg (1999) has explained previously that in order for CSCL to occur, peers who are more or less at the

same level perform the same action, have a common goal, and work together.

The utilization of technology reported in this study suggests an alignment with Dillenbourg’s (1999) description of CSCL. PSTs, who are at the same level, performed the same action of engaging in the planning and teaching of STEM. They had the common goal of furthering the development of their practice and they did so in collaboration with each other and as such were “working together.” Synergies between the conditions required for CSCL to occur and the collaborative, nonjudgmental, shared support and accountability required of PLCs suggests that taking a CSCL-based approach to the use of technology within PLCs is a natural and logical fit. We regard the use of mobile technologies reported in this study as an example of CSCL.

Context and Study Design

As a part of a STEM elective subject, which is undertaken in the final semester of their 2 year graduate Masters level degree, PSTs were required to teach a series of sequential lessons to primary school students taking an integrated STEM-based approach. Across the 3 years in which the elective subject has taken place, PSTs have worked with a number of schools in the inner suburbs of Melbourne, across an age range encompassing all of the primary years.

Before teaching within schools, PSTs have had opportunities to develop an ability to work effectively in PLCs through attendance at lectures and engaging in workshop activities designed to enable them to understand the different approaches that may be taken to establishing successful PLCs. For example, in addition to attending a lecture providing more general information about PLCs, PSTs also attended a lecture (from an international expert in the area) providing detailed information about Japanese Lesson Study (Iksan et al. 2014). They were then asked to draw links and synthesize the various materials.

Following, workshops and lectures, PSTs taught a sequential series of four weekly lessons to year 5/6 students (age 10–13). The data

reported here is taken from a year in which the focus for teaching was on Bees and Bee adaptations. Specifically, PSTs were to facilitate a student inquiry investigating, why there has been a dramatic decrease in bee populations over recent years.

During the teaching of each of the four lessons, a group would observe the teaching group and use their mobile devices to post short pieces of feedback related to the lesson that they were witnessing on “Padlet.” At the conclusion of the lessons, each week, each of the Padlets would be displayed on a data projector and the group that had observed the teaching group would facilitate a discussion providing feedback about the teaching group’s lesson. In the Padlet, users had the ability to upload multimedia and provide real-time succinct feedback to their peers. Notably, some feedback focused on mathematical understandings, while some was focused on pedagogical, technical, and organizational matters.

Across the 4 weeks, each contribution on each Padlet was coded and then aggregated in an effort to better understand on where the PSTs’ feedback was focused. Codes allocated to contributions were, “Science,” “Technology,” “Engineering,” “Mathematics,” “STEM” (indicating a contribution where concepts are integrated across the disciplines) and “General Pedagogy.”

In addition to data derived from the Padlet pages, we utilized qualitative data from three, online, open ended, anonymous surveys to gain an understanding of how PSTs perceived their experience of working within a mobile technology supported PLC.

Results and Discussion

The results and discussion are divided into two subsections. The first provides a number of excerpts of responses to an online survey that was completed by PSTs within the elective. Analysis of these excerpts provides some indication of how PSTs perceived the technology supported peer-observation process that was core to the subject. The following section provides the results of aggregated student peer feedback taken from

Padlet and some discussion of how these results suggest that PSTs focused their feedback.

PST Perceptions of Mobile Technology Supported Peer Observation Process

When asked about their perceptions of working within mobile technology supported PLCs and being part of the peer observation process, PSTs reported the following:

1. I learnt how to successfully collaborate as a team and gained loads of exciting ideas and ways to support and encourage learning in my classroom.

In excerpt 1, the PST suggests that the process of engaging in a mobile technology supported PLC-enhanced understandings of how best to collaborate. She emphasizes that she gained new ideas about creative approaches to teaching that she may not have had had access to if taking another approach to learning.

2. I was really interested to see how others use the 5E framework and pedagogical tools in different ways. I am always really interested when people do things in ways I never thought of.

Excerpt 2 shows that the PSTs valued the opportunity to observe their peers interpreting, through teaching, the learning they had all engaged in, in University-based workshops, in a classroom with “actual” students. An implication here is that, while the PSTs have many opportunities to discuss and clarify their thinking in University workshops, the opportunity to actually see each other teach provides an insight that is not possible through discussion only.

3. Mimicking the structure of how planning is done in schools, I think this was a valuable team experience. Sharing of ideas made the unit more diverse and interesting.

The PST shares their view, in excerpt 3, that through planning and teaching within PLCs reinforced by technology supported peer observation; the process was a more authentic and faithful representation of what they believe will occur in their working life as a teacher.

4. Great opportunity to teach a sequence of lessons to students and have feedback from peers and

lecturers. Liked working collaboratively as everyone brought ideas to the table which were critically reviewed so on the whole lessons were at a high standard.

The PST reflects in excerpt 4, that the process of peer observation and feedback was a very positive experience. They share their view that the opportunity resulted in overall high-quality lessons being planned and taught. It was interesting that the process of their teaching and planning being “critically reviewed” was seen as a positive, where this could easily be perceived in a negative way.

5. I feel far more confident in the teaching of STEM units. My knowledge background was strong and I was confident I knew the concepts very well. My experiences here have now given me the ability to know how to apply my knowledge and transfer the desired understandings to my students. Scaffolding their achievement of success criteria is achieved by designing appropriate activities and lessons that are hands on, engaging, student-led, and also, highly enjoyable and fun.

The PST, in excerpt 5, suggests that while their content knowledge in the various disciplines of STEM was strong, the process of engaging within the PLC and providing and receiving feedback through peer observation strengthened their pedagogical content knowledge. This aligns with data collected, reported in the following subsection, suggesting that feedback was focused more on pedagogical approaches, than specific content in the STEM disciplines.

6. It has been the most constructive process of science teaching I have experienced in the entire Master of Teaching course. The feedback has been excellent over the course to allow us to refine and develop the lessons.

PSTs, prior to engaging in the STEM elective, had not had the opportunity to observe each other teach or provide and receive feedback from each other on their teaching. Comments from the PST in excerpt 6 indicate that this was a very useful component of the elective. PSTs have received feedback and critiques of their teaching throughout the course from University academic staff and mentor teachers, in addition to a range of anecdotal feedback. Excerpts suggest that the PSTs, at times, value the feedback from their peers as more

meaningful than from individuals who they would consider to be assessing and judging them.

PST Focusses of Peer Feedback

Table 1 shows how PSTs focused their peer feedback within Padlet. It is clear that “engineering” and “technology” was not a focus of the teaching or of feedback. This can largely be explained. As previously stated, in the year that this data was gathered, the context for teaching was “Bees and Bee Adaptations.” While subsequent and previous years of the elective involved a greater focus on these disciplines, this context did not lend itself well to exploration and investigation with engineering and technology.

Interestingly, the data shows that PSTs were by far and away most concerned with focusing their peer feedback on general pedagogical issues, providing 204 contributions with this as a focus. The next closest, mathematics, received 66 contributions.

It was of interest to observe that while only marginally, mathematics was a greater focus of PST feedback than science. Given, the scientific nature of the context of this inquiry, we had anticipated that science would be a greater focus during these discussions. Additionally, some researchers in the field of STEM education claim that mathematics can often be overshadowed when working in a STEM context (English 2015). They suggest that science can be considered the “dominant” discipline within the term. Data collected here

Empowerment and Disempowerment in Peer Observation Within Pre-service Teacher, Technology-Assisted Integrated STEM Education, Table 1 Feedback from Padlet provided by PSTs, categorized by discipline

	Group A	Group B	Group C	Total
Engineering	0	0	0	0
General pedagogy	60	51	93	204
Mathematics	37	21	8	66
Science	19	11	25	55
STEM	6	1	5	12
Technology	0	2	0	2

Empowerment and Disempowerment in Peer Observation Within Pre-service Teacher, Technology-Assisted Integrated STEM Education, Table 2 Focus of peer feedback from Padlet

	Week 1	Week 2	Week 3	Week 4
Engineering	0	0	0	0
General pedagogy	59	45	48	52
Mathematics	0	14	36	16
Science	13	19	6	17
STEM	3	1	3	5
Technology	0	0	0	2

suggests that when working to develop and teach STEM-based inquiry learning, mathematics, if anything, was of marginally greater an emphasis.

Table 2 provides insight into how PSTs’ focus of feedback changed throughout the 4-week teaching sequence. While, there were a greater number of overall mathematics-focused contributions compared to science-based contributions, no contributions were focused within the area of mathematics in Week 1. We hypothesize that the scientific context of the teaching sequence was central to “setting the scene” for the investigation. Further evidence for our hypothesis relates to science-related feedback being in greatest evidence in the initial 2 weeks of the sequence.

Conclusions and Implications

Underpinning and supporting the peer observation process was a CSCL environment (Padlet) accessed through mobile technologies. A number of features were essential for mobile technologies to support PST feedback. These included equality of contribution. All participants also had equal ability and agency to contribute through their personal device. PSTs had multiple opportunities to contribute. Unlike face to face feedback, they could build on and develop their feedback over the course of the lessons. They had the opportunity to edit and modify their own contributions making the process more fluid and dynamic. It is believed that the use of mobile technologies enhanced the metacognitive practices of the observers. In addition to having the ability to

edit their own contributions, PSTs built on other PSTs contributions, allowing them to recognize aspects of the teaching process they may not otherwise have considered.

Critics of peer observation within PLCs have argued that the process is easily subverted. They suggest that it is easily manipulated by figures of authority, as an opportunity to ensure compliance and an opportunity to carry out surveillance (Shortland 2004).

Others suggest that staff are not qualified to judge their peers. There remains no definitive agreement about what constitutes the most successful teaching style or method; therefore any judgment or critique of peers relies on the (peer) assessor’s subjective view about what constitutes effective teaching practices (Cosh 1999).

We question how, when teaching at a school or tertiary level, even when a reflective approach to peer observation and feedback is utilized, can the power imbalance between observer and observee be reconciled?

We agree with Shortland (2004) that the approach regularly taken to peer observation and feedback in professional teaching environments usually provides only a small “snapshot” of what has occurred throughout a sequence of teaching. Thus, it becomes difficult for an observer to know how the session relates to the rest of the program. With this constraint in mind, the quality and value of feedback is compromised.

Despite these reservations, we see mobile technology supported peer observation within PLCs as part of PST education and training as fundamentally different. Our PSTs are enrolled in their course with the purpose of preparing to become primary school teachers. Thus, they are positioned, upon enrolment in their course, as learners.

Survey data, collected as part of this study, indicates that rather than feeling surveilled or viewing the process as an exercise in compliance, PSTs embraced the process as an authentic learning opportunity. Relative to the potential levels of disempowerment they experience when being observed by academic supervisors and mentor teachers, the process of observing and being observed by their fellow students is liberating, in that all participants in the process are striving to

achieve the same goal; becoming the best teacher possible.

Unlike examples provided in the literature (Cosh 1999; Shortland 2004; Hammersley-Fletcher and Orsmond 2004), observers were able to view the entire teaching sequence (occurring over 4 weeks). Thus, PSTs were able to see how the sequence unfolded, avoiding issues associated with an observer having a disconnected understanding of how the teaching cohesively came together.

In addition, to gaining an understanding of how our PSTs perceived the process of technology supported peer observation within PLCs, we were interested in how our PSTs would focus the feedback that they posted in the CSCL environment (Padlet). It had been anticipated that the content focus of their feedback may predominantly lie in the area of science, as a result of literature suggesting that mathematics is often overshadowed within a STEM education context (English 2015). However, as reported, mathematics was of a slightly greater emphasis in PST contributions within the CSCL environment.

It had not been anticipated that the overwhelming majority of feedback would relate to observations and suggestions about general pedagogy. It may be that the PSTs felt more secure and confident offering feedback related to broader pedagogical issues. It is also possible that given that the teaching sequences were collaboratively planned amongst the PST cohort, there was a common understanding of the content being taught; therefore, PSTs had less need to focus feedback on content areas. In the moment, pedagogical choices, however, are not necessarily shared understandings and therefore would compel observers to provide commentary or feedback.

Interestingly, no mathematics-centered feedback occurred in the first week of data collection. We have argued that science has provided a context, or a tangible narrative, from which to “steer” the STEM sequence of learning. Therefore, it is a major focus of feedback in the initial 2 weeks.

We suggest an implication for the planning of STEM sequences of learning, or for a general framework for STEM units, that science can be

considered the “host domain,” from which engagement in the learning is launched.

Mathematics is later utilized within the STEM sequence of learning as a tool for the interrogation and analysis of data, helping to communicate understanding. Neither discipline need be overshadowed. Instead PSTs can be encouraged to achieve balance, utilizing science and mathematics in a purposeful, targeted, and synergistic manner.

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E-Portfolio in Higher Education

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Introduction

The 1970s and 1980s of the twentieth century witnessed a great transformation of focus toward direct measures of writing. As a result, the portfolio was introduced as a means to examine real samples of students' writing especially in disciplines with significant writing components (Lorenzo and Itelson 2005). Therefore, a

portfolio can be seen as an exhibition of student work that provides real evidence of achievement. In fact, Linn and Gronlund (2000) used the term “student learning portfolio” to refer to the collection of examples of student work annotated with student's reflective commentary. These examples can be curricular activities, such as course assignments and projects, or cocurricular activities such as sports, music, drama, etc. By facilitating students' reflection on their own work, student learning portfolios can help students become more aware of their learning and needs.

The rapid development of Web technologies and the increased availability of Web-based platforms have introduced a huge number of e-learning tools that have greatly contributed to the improvement of teaching and learning as well as the enhancement of academic performance (Alhazmi and Rahman 2012). Electronic portfolio (or e-Portfolio) is one of these innovative e-learning tools that have proved to be of great value in monitoring students' progress and enhancing their educational outputs. According to Eynon et al. (2014), this pedagogical tool can improve student learning through recognition and synthesis of ideas, reflection, self-evaluation, self-awareness, and action planning and goal setting.

An e-Portfolio is a collection of student work constructed electronically on the Web or on any recorded media such as CDs, DVDs, Zip disks, etc. This collection, which is usually managed by the student, contains electronic evidence (called artifact) in the form of text, files, images, audio and video files, blog entries, and hyperlinks. The hyperlinks enable the student to make connections between and among classes, experiences, and observations. Being electronic makes e-Portfolios more flexible, more portable, and easier to share. It also enables students to reuse entries in different presentations and for different views and contexts. Therefore, the “e” in e-Portfolios adds more value to their use in education (Yancey 2001). While the focus of print portfolios is mostly on the course level, the focus of e-Portfolios extends to the whole curriculum as well as to outside experiences (Yancey 2009).

In a broad sense, Kunnari and Laurikainen (2017, 7) defined e-Portfolios as “student-owned digital working and learning spaces for collecting, creating, sharing, collaborating, reflecting learning and competences, as well as storing assessment and evaluation. They are platforms for students to follow and be engaged in their personal and career development, and actively interact with learning communities and different stakeholders of the learning process.” This broad and comprehensive definition makes the experience of creating and developing e-Portfolios meaningful and learning-rich for students. Belgard (2013) stated that the creation and sharing of evidence and artifacts in the e-Portfolios develop students’ collaborative skills. Moreover, the reflection involved in the creation of these e-Portfolios promotes meta-learning, which puts the students in the state of being aware of and having control over their own learning. It’s worth to mention that without this reflection, the value and richness of e-Portfolios are diminished (Ramey and Hay 2003).

According to Swan (2009), students usually upload artifacts to a Web server where they get tagged and then stored in a database. Tagging is not only essential for the storage and retrieval of the artifacts but also for the reflections and feedback that can be added to these artifacts. Students can filter and sort the artifacts to create completed portfolios for their courses or programs. This process of e-Portfolio creation and development was recognized by Danielson and Abrutyn (1997) who divided it into five stages:

1. Collection: where students learn to save artifacts that represent the success and growth in their teaching and learning
2. Selection: where students review and evaluate the artifacts and select those that best demonstrate achievement
3. Reflection: where students reflect on the artifacts as well as on the whole e-Portfolio
4. Projection: where students review their reflections on learning and set goals for the future
5. Presentation: where students share their e-Portfolios with others

Over the last decades, there has been a rapid increase in the utilization of e-Portfolios in higher education (Baris and Tosun 2013). In fact, e-Portfolios have been largely integrated into the education settings of the institutions of higher education all over the world (Hohlfeld et al. 2008; Zubizarreta 2009). Compared with other technology applications, e-Portfolios are believed to have a greater impact on higher education (Batson 2002). Trevitt et al. (2013) posited that e-Portfolios can play a crucial role in screening university graduates who are expected to demonstrate certain skills, such as higher-order thinking, communication, and collaborative abilities.

Bringing e-Portfolios into institutions of higher education is a challenging process. However, with deep motivation and determination, this process can be less challenging and more successful. Recently, Sellami (2017) conducted a case study to implement an initiative of introducing an e-Portfolio into a master’s degree program at a Tunisian university. He found out that students not only enjoyed creating their e-Portfolio, but they also realized its positive impact on their learning, career planning, knowledge acquisition, and the development of their skills. Furthermore, he concluded that the e-Portfolio encouraged self-reflection among students and helped them showcase their talents.

Benefits of E-Portfolios

The literature has documented a number of benefits of using e-Portfolios in the learning environment. These benefits include, but not limited to:

- Technology skills: By working on their e-Portfolios, students develop technology, writing, and multimedia communication skills (Bartlett 2002; Barbera 2009; Wakimoto and Lewis 2014).
- Learning through reflection: E-Portfolios allow students to evaluate their learning processes and outcomes by self-reflection and comments from others. Considered interactive platforms, these e-Portfolios can help students recognize personal strengths and weaknesses

in skill acquisition and development (Roberts et al. 2013; Sellami 2017).

- Career development: E-Portfolios make it easy to share the collection of work samples and skill demonstrations with potential employers (Reese and Levy 2009). They provide a rich source of information for employers and professional organizations (Simmons and Williams 2012; Reardon et al. 2007).
- Organizational ties: E-Portfolios can strengthen the organizational ties with students even after graduation. They can also establish connections with prospective students (Reese and Levy 2009).
- Student assessment: By providing authentic assessment, e-Portfolios can be useful in both formative and summative assessment of students (Liu et al. 2004; Reardon et al. 2004; Sellami 2017).
- Work readiness: E-Portfolios demonstrate student work readiness by providing evidence of individual growth (Basken 2008).

Types of E-Portfolios

The e-Portfolio literature has documented three main types of e-Portfolios that support different assessment purposes (Hewett 2004; Mason et al. 2004; Willis and Wilkie 2009):

- Documentation (personal developmental) e-Portfolios show the growth toward achieving specific, pre-defined learning goals. They can also be used to monitor the advancement of skills over a period of time. These e-Portfolios enable students to develop, display, and reflect on their own learning. For assessment, developmental e-Portfolios support diagnostic assessment by providing a communication channel for students and instructors to plan and check how learning is progressing.
- Assessment e-Portfolios document the phases of the learning process and reflect upon the students' journey toward mastery. They make students aware of how they learn best. This type of e-Portfolios supports self-assessment and can help instructors in their assessment

by capturing the different aspects of student learning.

- Showcase (presentation of products) e-Portfolios highlight students' accomplishments and competences. Since they include graduates' best works and products, these e-Portfolios are usually presented to potential employers in job applications. This is why sometimes they are called career e-Portfolios. It's worth to mention that this type of e-Portfolios supports summative assessment of students' competences and learning outcomes.

Challenges to the Use of E-Portfolios

As explained earlier, a huge volume of research has indicated that e-Portfolios can have a positive impact on the learning experience. In higher education, this innovative technology plays a vital role in enhancing learning, conducting assessment, meeting standards, and increasing student employability. However, this does not imply that e-Portfolios are the panacea for all diseases because there are significant challenges that may limit their effectiveness and utilization (Cheng 2008; Lee 2007).

One of the main challenges that face institutions of higher education is the time-intensive nature of the development of e-Portfolios, especially when used with large classes and groups. In a recent study, Sellami (2017) concluded that although most students appreciated the use of e-Portfolio, they found it time-consuming. He also declared that enhancing the use of e-Portfolio caused extra hours of teaching load for instructors. Therefore, students and instructors may become reluctant to the use of e-Portfolio because they expect a heavy workload.

Another serious challenge to the use e-Portfolios is related to student's development of basic critical skills, such as collecting, selecting, and reflecting on potential material. Milman (2005) emphasized that students need to learn how to select, collect, reflect, write, and respond to feedback for e-Portfolio assessment. For instance, she mentioned that selecting what to put into the e-Portfolio was difficult for both students who

had lots of evidence of student teaching (e.g., activities, papers, lesson plans, etc.) and those who had not yet experienced student teaching. According to Sharma and Mishra (2006) and Zubizarreta (2009), without a significant focus on reflection, e-Portfolios may simply become a collection of information rather than a means to support personal development and reflective learning.

Hughes (2008) addressed an important challenge related to instructors. He pointed out that the use of e-Portfolios may require instructors to change the traditional assessment practices in their courses. They should be prepared to engage with their students in meaningful individual and collaborative activities that develop comprehensive interactive cultures. They should also prepare relevant rubrics and marking guides to overcome the subjectivity of the e-Portfolio-based assessment.

The use of e-Portfolio system can be hindered by significant technical challenges. According to Peacock et al. (2010) and deFreitas and Jameson (2006), these technical challenges may include, but not limited to:

- Lack of compatibility of different e-Portfolio systems and their functionality
- Lack of availability of computers and problems with access to the Internet
- Unavailability of the e-Portfolio systems due to site maintenance and frequent updates
- Limited technical knowledge and proficiency among students and instructors
- Issues of privacy and security of data
- High initial operating costs
- Adaptability for various purposes

E-Portfolios as an Assessment Tool

Since assessment for learning plays an important role in higher education, instructors have shifted their attention from traditional standard tests to new assessment methodologies that enable students to prove their skills when solving problems, reflecting, analyzing, and synthesizing. O’Keeffe and Donnelly (2013) asserted that e-Portfolios

enhance assessment and feedback and foster creativity and, therefore, can be valid and reliable tools for learning assessment. In fact, assessment can benefit from e-Portfolios’ collection of various samples of student work since it provides a larger, more detailed view of student’s knowledge and achievements. Furthermore, according to Smolyaninova and Shilina (2011), e-Portfolios enhance objectivity of assessment by increasing the number of people involved in it and help to make instructors’ assessment more transparent. Therefore, it is essential that instructors take advantage of e-Portfolio assessment (Yilmaz and Çetinkaya 2007).

Rao et al. (2012) declared that e-Portfolios not only store achievements but also demonstrate the processes of accomplishing those achievements. This, of course, gives e-Portfolios an advantage over traditional forms of assessment (Donnelly et al. 2010; Lambert et al. 2007). In fact, e-Portfolio assessment has moved above conventional assessment to a level where student learning is deeply facilitated and enhanced. Therefore, institutions of higher education have urged students to develop e-Portfolios for the purpose of summative assessment, self-directed learning (formative assessment), and employability (Lam 2015).

Literature has witnessed a huge volume of studies that examined the use of e-Portfolio assessment to produce positive outcomes. Recently, Roberts et al. (2016) conducted a study that investigated the effect of an e-Portfolio-based learning environment on preservice teachers’ reflection abilities. Based on the findings, the researchers concluded that the e-Portfolio environment was effective in scaffolding students’ reflective thinking. The same conclusion was underlined by Montgomery (2003) and Lynch and Purnawarman (2004) who stated that e-Portfolios are important vehicles for supporting critical thinking of learners with reflective thinking actions.

The study by Gulbahar and Tinmaz (2006) showed that the use of e-Portfolios helped students to overcome their anxiety and promote their confidence. The study also showed that students liked the e-Portfolio assessment system

incorporated into their courses. In the same manner, Sellami (2017) found out that students did appreciate the fact that their evaluation was based on their e-Portfolios, rather than on their performance on classical examinations. Similarly, Akçıl and Arap (2009) concluded from their study that all students liked the use of e-Portfolio where more knowledge occurred at the end of the e-Portfolio process.

Ragusa (2010) indicated that in higher education, e-Portfolios are gaining prominence as an assessment tool. They are being used increasingly, especially in terms of demonstrating skills, abilities, and achievements against certain competencies or criteria (MacEntee and Garii 2010; von Kinsky and Oliver 2012). Furthermore, e-Portfolios not only can provide ways for students to use feedback from assessment to support their learning but can also enhance their professional activities (Kocoglu 2008). Some researchers emphasized the potential of e-Portfolios to support what's called "integrative learning," where class and work experience are integrated together and knowledge or skills are presented across various classes (Eynon 2009; Light et al. 2009).

Over the last two decades, e-Portfolios have become more common in teacher education programs at institutions of higher education as a tool for assessing preservice teachers. Carney (2004) concluded from seven case studies that e-Portfolios of preservice teachers are actually their autobiography as a teacher depicting their philosophies of education. Donaire et al. (2010) viewed e-Portfolios as a perfect follow-up tool to document students' competences development through their degree studies. Therefore, it's been deeply believed that e-Portfolios are the right tool to track the general competencies acquired by teachers, including content knowledge, knowledge of learning and learners, pedagogical skills, learning environment, assessment, instructional technology, school and community engagement, ethics, and professionalism (Anderson and DeMeulle 1998; Naizer 1997; Reis and Villaume 2002; Simmons 1996). Currently, most teacher education programs require prospective student teachers to develop and present an e-Portfolio of

evidence as part of their graduation qualifications (Groom and Maunonen-Eskelinen 2006).

Some institutions of higher education have taken the e-Portfolio assessment to a higher level where the collections of student artifacts with reflection are utilized in assessing the effectiveness of their courses, curricula, and programs (Bates 2010; Van Aalst and Chan 2007).

The implementation of e-Portfolios as an alternative assessment strategy in the institutions of higher education has been the subject of a large number of research studies. Salvia et al. (2007) and Van Wyk (2017) have put forward several suggestions for the successful integration of e-Portfolio assessment:

- Imbedding the e-Portfolio assessment in the curriculum and aligning it with the learning outcomes.
- Developing intended outcomes related to the purpose and objectives for using and implementing e-Portfolio assessment.
- Instructors need to be aware of the virtues of the inclusion of e-Portfolios as part of the work integrated learning requirement.
- Overcoming the financial needs that result from rethinking of curriculum evaluation.
- Developing clear assessment criteria for evaluating e-Portfolios. These criteria need to be clarified to students and assessors.
- Integrating the use of e-Portfolios within assessment plans.
- Encouraging cooperation among students as well as between students and their instructors.
- Designing tasks that illustrate work in the real world. Instructors need to focus on authentic problems and assignments.
- Encouraging student reflection.

Conclusions

E-Portfolios are not a new concept; they have been in use in education for more than a few decades. E-Portfolios have proven to provide richer, transformative educational experiences for students. They enable students to share information, collaborate with others to complete tasks,

and reflect critically on their work. Therefore, e-Portfolios have the capacity to become lifelong learning tools.

E-Portfolios are vital for students' development because they have the potential to be a learning tool, an assessment tool, and a record of achievement. Their great potential of assessment has gained attention among institutions of higher education.

The implementation of e-Portfolios in higher education can have a spectrum of educational values, including the increased ability of students to achieve learning outcomes, better communication between students and instructors, active participation in the classroom, development of critical thinking skills among students, making students aware of their learning, and enabling students to take control of the learning tasks.

However, e-Portfolios are not without their challenges. These technical and pedagogical challenges can limit the effectiveness of a long-term, institutional implementation of e-Portfolios. Among these challenges, the following can be mentioned: time-consuming, students' need to develop basic critical skills, changing the traditional assessment practices, and several technical challenges and issues.

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Ethics and Learning for Teacher Trainees, Team-Based Simulations in Cases of Bullying in School

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Synonyms

[Case-study](#); [Ethical dilemmas](#); [Psychological Empowerment](#); [School bullying](#); [Teacher trainees](#); [Team-based simulation](#)

Introduction

Ethical Dilemmas in Teaching

Society expects teachers to be guided by ethical principles in dealing with the bullying they encounter. Teachers are perceived as professionals who help shape the image of society and should be capable of making ethical decisions for the general good. As ethical agents, they shape coming generations of citizens (Aloni 2013; Barrett et al. 2012).

Ethical dilemmas in teaching are defined as complex situations that usually entail ethical conflicts for which teachers and educators are required to provide appropriate responses (Shapira-Lishchinsky 2013; Bullough 2011).

Studies indicate that dealing with ethical dilemmas helps educators to develop emotionally, morally, and operatively. *Emotionally*, dealing with ethical dilemmas emerges teachers' feelings of empathy and solidarity, recognition of others' feelings and emotional and existential state, as well as concern for assuring their dignity and welfare (Aloni 2006, 2013). *Morally*, by engaging in such dilemmas, teachers elevate the importance of basic human values and egalitarianism. It also encourages moral judgment based on concepts of universal human rights. It stimulates rational thinking, autonomy, neutrality, and consistency. In addition, by dealing with ethical dilemmas, individuals strive internally to adhere to a moral stance in the face of temptations and obstacles, whether internal or external (Aloni 2006, 2013; Cohen 2015; Shapira-Lishchinsky 2013).

Operatively, studies show that familiarity with a variety of ethical dilemmas and of ethical principles assists teachers in constructing a professional toolbox. Analyzing cases and mapping their component parts and proposing several possible options for actions provide teachers with tools that they can use when facing similar situations in the future. More generally, dealing with ethical dilemmas helps members of an organization to find a common ground and to create unanimity of ideas about the basic human values that guide them as a professional group (Aloni 2006; Davidoff 2016; Gevton 2011; Shapira-Lishchinsky 2013, 2016).

Teachers confronted with ethical dilemmas related to bullying at school feel powerless and unsupported by the education system (Dedousis-Wallace et al. 2014; Gaikhorst et al. 2014; Shapira-Lishchinsky 2013). Various studies show that most teachers complete their training without any reference to bullying being one of their key professional difficulties. They feel a need for operational experience-based training, in a protected, cooperative environment, that will enable them to acquire operative skills to deal with bullying in school (Lindqvist et al. 2017; Sela-Shayovitz 2009).

This article proposes the use of team-based simulations (TBS) (role-playing) and video-based reflections to train teacher trainees to deal with ethical dilemmas related to school bullying. School bullying is a widespread, global phenomenon that disrupts educational activity (CDC 2017; Fishman 2015). Two recent studies, one sponsored by the United Nations (UNESCO 2017) and the other by the World Health Organization (WHO 2016), revealed the extent of conflicts and bullying in schools. According to the 2016 UN research, 29–46% of school-age children worldwide suffer from bullying on a regular basis (UNESCO 2017). The WHO (2016) research, which relates to OECD countries, found that 33% of the students reported having been victims of bullying or harassment at various levels of power at least once in the past 2 months and 14.7% of the students reported various attacks on school premises (CDC 2017). The problem attracts much public, social, and academic attention, and globally it is considered a key problem in societies that see school as agents of socialization (CDC 2017; Harel-Fisch et al. 2011).

The use of simulations promotes a sense of psychological empowerment in coping with ethical dilemmas in school, and it encourages cooperation and reflective group thinking in a pleasurable and experiential environment of learning that motivates the learning experience (Davidoff 2016; Shapira-Lishchinsky 2014; Walter and Adam 2014). Another important aspect is the use of video as part of the reflective process during the simulations that enhance deeper understanding of critical situations. Watching extracts from filmed simulations in reflective team discussions helps participants to gain insights of verbal and nonverbal messages such as tone of voice and body language. It also enables the participants to evaluate and analyze their own responses and behaviors. It promotes their understanding of the impact of their behaviors and decisions (Davidoff 2016; Harford and MacRuairc 2008; Masats and Dooly 2011; Shapira-Lishchinsky 2016).

Moreover, the focus of this article on simulations is based on previous studies which indicate that the use of simulations leads to an applicative transfer of operative memory structures in the brain (Bar 2011; Kwanghyun and Soyeon 2016). These operative experiences acquired through simulation stay in the learners' brain as a real-life experience. Furthermore, the simulations make it possible to predict and later on to use strategies in real life that were internalized in similar cases encountered previously during simulations (Bar 2011; Kwanghyun and Soyeon 2016).

School Bullying and Its Consequences

"Bullying" refers to any form of attack with or without the use of physical force. It includes "violence," which refers to acts that include the use of physical force and is only one of the many forms of bullying (Fishman 2015). School bullying can be defined as follows: directed behavior intended to emotionally or physically harm other people, their property, or school property (Cornell and Limber 2015). Students who are bullied experience feelings of anxiety, lack of protection, dissatisfaction with life, and high levels of depression, including suicidal thoughts. These facts are stated to turn school bullying into a problem that threatens the education system (Bonanno and Hymel 2010; Burger et al. 2015; CDC 2017).

Bullying Prevention Program for Educators

Research indicates that most educators are extremely disappointed by lack of attention bullying receives in teacher training curricula. Bullying is seen as being a low-priority issue when compared to teaching theoretical content and learning academic teaching-learning strategies (Gaikhorst et al. 2014; Sela-Shayovitz 2009; Shavit and Blank 2010). Studies have shown that educators have a need to practice and

apply alternative methods of coping with bullying in a supportive environment. These include opportunities for sharing experiences, ideas, and opinions about ethical challenges they encounter (Shapira-Lishchinsky 2013; Gaikhorst et al. 2014). Previous studies emphasize the importance of workshops as a means of preparing teacher trainees for dealing with bullying hyphenated ethical dilemmas in a practical and protected way that reflects their daily needs as professional teachers (Sela-Shayovitz, 2009).

Ethical Dilemmas in Dealing with Bullying

Ethical dilemmas in bullying are described as complex situations that usually entail ethical conflicts. Educators are required to provide appropriate responses to such dilemmas (Poliner Shapiro and Stefkovich 2016) and are expected to work according to ethical principles to be able to make ethical decisions while dealing with school bullying (Bullough 2011).

Studies indicate that challenging educators with ethical dilemmas helps them acquire knowledge and skills to deal with them effectively (Aloni 2013; Barrett et al. 2012; Gevton 2011; Poliner Shapiro and Stefkovich 2016). From a moral perspective, engaging in ethical dilemmas as part of their training enhances educators' egalitarianism and moral judgment. From an operative perspective, engaging with these ethical dilemmas assists educators in developing skills that help them create consensus around ideas about basic human values (Aloni 2006; Shapira-Lishchinsky 2013).

Studies show that teacher trainees feel professionally inadequate and powerless when dealing with ethical dilemmas related to bullying scenarios and that they have limited means of action. Hence, they feel uncertainty (Lindqvist et al. 2017; Sela-Shayovitz 2009). In resolving ethical dilemmas and professional inadequacy, trainees tend to depend on colleagues to help them deal with bullying (Sela-Shayovitz 2009).

Meta-cognitive Thinking in Dealing with Bullying

“Meta-cognitive” refers to the individual’s ability to think about his/her thinking, to plan and navigate his/her own cognitive processes, and to make informed decisions (Flavell 1970). Behaving in this way, educators are perceived not only as thinking individuals but also as self-regulators capable of assessing and directing themselves to specific behaviors. Meta-cognitive strategies include the active development of thinking skills such as structuring and integrating new information with existing information, planning, assessing progress, and improving performance by self-check and assessment (Flavell 1979). These strategies assist learners to cope with and analyze ethical dilemmas involving bullying (Jenkins 2012).

Previous studies indicate that reflective and meta-cognitive thinking can significantly affect the treatment and prevention of bullying in school (Burger et al. 2015; Strohmeier et al. 2012). These studies noted that professionals are more likely to make quality ethical decisions when they are participating in a meta-cognitive process (Christensen and Kohls 2008). Engaging in team-based reflective discussions and meta-cognitive thinking processes helps educators to improve their pedagogical approach to bullying-related ethical dilemmas. Educators who engage in such processes manifest rich theoretical knowledge and investigative-critical thinking. Furthermore, when dealing with bullying-related ethical dilemmas, these educators display fewer fears about their professional position and greater feelings of professional autonomy as well as ethical commitment to their work and to their teaching colleagues (Burger et al. 2015; Shapira-Lishchinsky 2013; Strohmeier et al. 2012).

Training by Team-Based Simulations

Simulation is defined as a model of reality that includes elements of role-playing (Walter and

Adam 2014). Simulations provide learners with the opportunity to “step into the shoes” of figures involved in the situations under discussion. When faced with similar events in real life, individuals can extract subconscious behaviors learned from these simulations (Bar 2011; Kwanghyun and Soyeon 2016). Simulations encourage collaboration as well as reflective thinking through investigating ethical dilemmas by role-playing (Anderson and Lawton 2009; Clark 2007; Walter and Adam 2014).

Previous studies indicate that when a person predicts behavior in a given situation and develops his future episodic thoughts, he needs an earlier acquaintance with the subject (Atance and Hanson 2011; Barsalou 2009). It was found that when simulations are used, a physiological (sensory, visual, auditory) memory of the situation is created. This memory improves the ability to assimilate action strategies based on reflective thinking for future use. In fact, as these strategies are applied in the memory, they become available and easier to retrieve in reality events (Atance and Hanson 2011; Barsalou 2009; Liberman et al. 2011).

According to Bar (2011), the person retrieves the information he stored in his memory, similar to the kind stored in a script library. These operational memories neutralize the disturbance of surprise that causes restlessness and contribute to the development of the person’s emotional, cognitive, and operational abilities (Barsalou 2009; Panichello et al. 2013). Through simulation, educators develop a sense of mutual assistance, which increases their self-confidence as well as their willingness to expose their difficulties and weaknesses to other team members (Shapira-Lishchinsky 2013).

Studies supporting the use of video during simulation workshops suggest that learning not only occurs during role-playing but also continues and deepens during the investigative stage. In this second stage, the participants analyze the events by watching role-playing videos and discussing a range of solutions before making a decision. Previous studies have indicated that the use of video improves practical thinking about

pedagogical strategies and increases participants' psychological empowerment (Davidoff 2016; Harford and MacRuaric 2008; Masats and Dooly 2011; Shapira-Lishchinsky 2016).

Psychological Empowerment and School Bullying

Psychological empowerment is defined as "intrinsic motivation reflecting a sense of self-control in relation to one's work and an active involvement with one's work role" (Seibert et al. 2011, p. 981). Psychological empowerment is composed of four cognitions: significance, self-definition, ability, and influence. Psychological empowerment in performing tasks is the relationship between individuals' beliefs, values, and standards and their professional functioning. Since the 1980s, interest has been growing in psychological empowerment in the context of motivation, quality of decision hyphenated, and task performance and in terms of its effect on the ability to cooperate effectively in team processes in a manner that contributes to personal and organizational growth (Kwanghyun and Soyeon 2016; Seibert et al. 2011).

Empowerment in school is characterized by assuming responsibility leading to professional growth. Teachers with high psychological empowerment tend to feel that they have the skills and knowledge necessary to improve their actions and solve problems effectively. Generally, they see themselves as personally efficacious, free to make decisions, influential in terms of applying strategies, and empowered by the organization to introduce change. Research has also shown a positive correlation between teachers' psychological empowerment and their commitment and performance while dealing with student bullying (Avidav-Unger et al. 2011; Chen and Chen 2008; Kwanghyun and Soyeon 2016; Sprietzer 1995).

Among teacher trainees, high levels of psychological empowerment may encourage educators' teaching efforts, their willingness to adopt new approaches to increase their students' learning,

and their level of perseverance when faced with obstacles (Hungafu 2012). In addition, a study among 90 teacher trainees, which compared the use of simulations to train teacher trainees to deal with ethical dilemmas in cases of school bullying, indicated that the use of group simulations, combined with reflective discussions, contributed significantly to the trainees' psychological empowerment (Davidoff 2016). According to this study, students who used simulations as part of group reflective discussions had a significant increase in their "self-confidence and sense of control" and their "capability of making rational decisions" (two aspects of psychological empowerment). Furthermore, the group who used simulations created an extensive variety of possible solutions for the ethical dilemmas, better team cooperation, and a higher propensity to promote empathy and openness in confronting complex ethical challenges. These findings are consistent with other research (Darling-Hammond et al. 2009; Hungafu 2012; Sprietzer 1995) that argue that active learning (such as role-playing) enhances teachers' capability to deal with ethical dilemmas in daily functioning. Thus, participants gain greater self-confidence, feelings of control in their decision-making, and empathy.

Various factors have been shown to enhance educators' self-empowerment: a climate of sharing and inclusion, teamwork, and active decision-making pertaining to their work (Kwanghyun and Soyeon 2016; Shapira-Lishchinsky 2014; Sprietzer 1995). Research also shows that psychological empowerment in schools enables educators to take more educational initiatives and improve their ability to cope with difficulties and ethical dilemmas in school.

In the context of dealing with bullying at school, it is important for schools to open the door and take notice of educators' need to learn in an experiential and reflective way, of the kind suggested by the use of simulations. These schools will enjoy committed and psychologically empowered educators, more able to cope with the difficulties that are part of their daily life around bullying.

Contributions of Team-Based Simulations

A deep insight into research confirms the benefits of conducting simulation workshops combining reflective meta-cognitive discussions. Team-based simulations will enhance teachers psychological empowerment to deal with bullying. According to research, the use of simulations contributes to the psychological empowerment of teacher trainees in terms of their self-confidence and decision-making in real bullying situations (Davidoff 2016). Empowered teachers tend to view themselves as characterized by personal efficiency, freedom to make decisions, and strategic-applied influence and with a sense of capability to effect change. Simulations also help reduce teachers' feelings of helplessness in various bullying situations encountered in their work (Davidoff 2016).

Additional benefit for dealing with bullying is that educators are more likely to get a better understanding of the needs of all parties involved. It leads them to an egalitarian way of thinking and to a wide view of problems and solutions (Aloni 2013). Moreover, simulations enhance educators' abilities to predict the effects of different behaviors and responses in conflict situations (Kwanghyun and Soyeon 2016). While participating in simulations, educators experience situations similar to those they are likely to experience in the future. This enables them to manage future thinking and planning processes by creating predictive processes in their brain (Bar 2011). Additionally, simulations contribute to teachers' decision-making while dealing with conflict situations. Simulations enhance teachers' creativity and quality of decisions and actions. According to neuroscience studies, simulations contribute to the development of the frontal cortex, which is responsible for the ability to make effective decisions related to social situations and to make more developed and applied decisions, rather than decisions made in the same context without simulations (Bar 2011). In dealing with bullying, it was found that role-playing for bullying cases tends to encourage a wider range of creative ideas and empathy toward students and

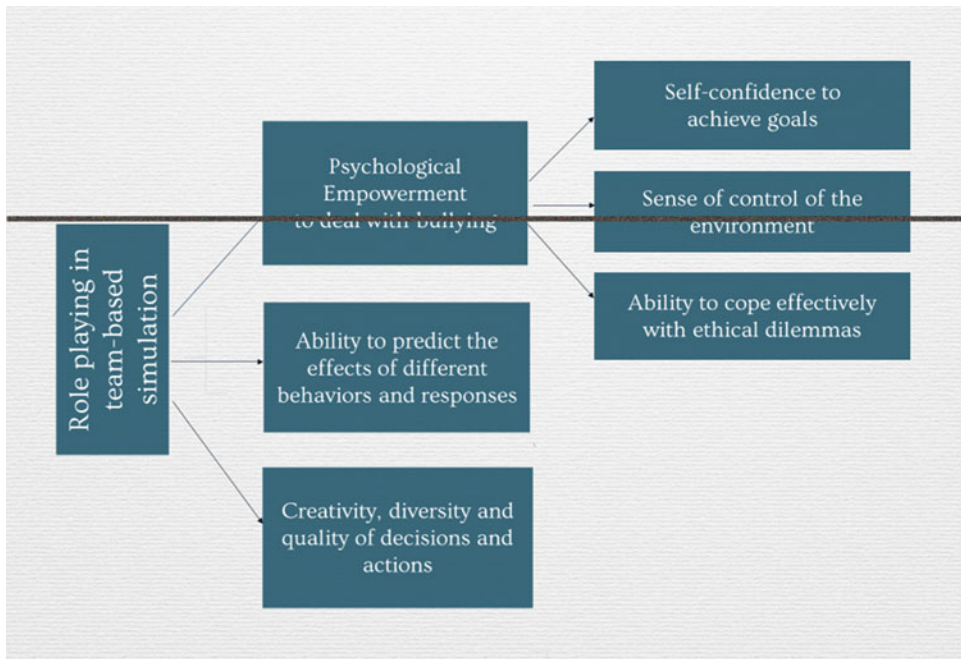
colleagues (Davidoff 2016). The key benefit of the use of team-based simulations in educating teachers to deal with school bullying is summarized in Fig. 1.

To summarize, this article focused on the effects of team-based simulations, incorporated in meta-cognitive reflective discussions of teacher trainees to deal with school bullying. We focused on trainees' psychological empowerment and their ability to develop evaluation as well as solutions to ethical cases around this concerning problem.

Even though school bullying is a worldwide problem, most teacher trainees do not participate in bullying prevention training programs. This situation creates frustration and feelings of helplessness. Thus, this article suggests that from research findings, simulation is an effective way of educating teacher trainees to deal with ethical dilemmas related to school bullying. Moreover, simulations and reflective discussions contribute to the assimilation of possible solutions for ethical dilemmas faced by teacher trainees. These solutions remain in the participants' subconscious memory and can be used daily in their capacity as teachers. Furthermore, the simulations, which take place in a supportive and risk-free environment, offer a method for learning that is experiential and enjoyable.

Future Research

It is recommended by research that future studies examine how simulations for teacher trainees affect school students over time, as well as the level of bullying in school. Also, in order to learn more broadly about the effects of simulations on learning, it is recommended to extend the use of simulations to different populations (e.g., high schools/special education) and other disciplines (e.g., engineering students/entrepreneurs). Expanding the research around the use of simulations in different disciplines is extremely important since according to previous studies (Arias et al. 2018), there is a growing need for students in different disciplines to include experiential learning in their qualification processes.



Ethics and Learning for Teacher Trainees, Team-Based Simulations in Cases of Bullying in School, Fig. 1 Key contributions of team-based simulations

This need is expressed in universities in order to better prepare students from different disciplines to deal with ethical dilemmas and challenges they are likely to encounter in their professional and personal lives.

Cross-References

- [Blended Learning](#)
- [Collaborative Learning and Patterns of Practice](#)
- [Games, Simulations, Immersive Environments, and Emerging Technologies](#)
- [Intercultural Education in the Digital Age](#)

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Ethnographic Researchers

- [Safe Frames, Essential Determinant for Educational Technology Implementation in an Indigenous Context](#)

Evidence-Based Learning

- [Capturing Learning Through Mobile Device Cameras](#)

Evidence-Based Practices

- [Exploratory Study Using Self-Regulated Self-Development \(SRSD\) and Technology in the Context of the Classroom](#)

Experiential Learning

- [Predicting ICT Skills and ICT Use of University Students](#)

Exploratory Study Using Self-Regulated Self-Development (SRSD) and Technology in the Context of the Classroom

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Synonyms

[Evidence-based practices](#); [ICT tools](#); [Personalized learning](#); [Primary schools](#); [Self-regulation](#); [Teaching-learning process](#); [Writing](#)

Introduction

The use of Information and Communication Technologies (ICT) in the context of writing is increasingly natural, and as a result, this interaction has caused changes in the nature and contexts of communicational processes (interpersonal, virtual, digital, and textual). This use of ICT has also changed the writing process making it more diverse and integrating with new writing formats (e.g., linear, multimodal), which may occur in different contexts (e.g., synchronous or asynchronous, individual, collective, or collaborative), and enforces the integration of digital literacy by the school (Lacina and Griffith 2012).

The integration of technologies in the classroom context is a necessity and a potential for the learning processes involving several teachers and students, with different characteristics, knowledge, and experiences. Although tools that can aid in the learning processes are well-known, there are many questions about how best to integrate these resources into classroom learning and how to manage individual differences (MacArthur 2009).

Primary school classrooms are filled with diversity that constantly challenges the teacher's role as facilitator and enabler in the process of developing children's writing skills. However, many teachers feel unable to help their students overcome their writing problems and feel that students tend not to like this type of activity (Araújo 2017). Reasons for these difficulties highlight the lack of training, time, or skills to respond to the current needs of children's literacy (Cruz 2009), who must write both in the analog and digital context. However, there is a strong relationship between ICT and schools or vocational writing (Tavares and Barbeiro 2011). Besides, there is a strong relationship in the uses of ICT in education (MacArthur 2009).

Unfortunately, many students struggle with writing problems because writing is a demanding, slow, and complex process. Students need time to understand the writing process, including writing conventions. Teachers also need to use explicit teaching practices and promote supported writing time. However, sometimes, teachers do not provide adequate responses to their students' difficulties.

In the classroom writing learning process, some students continue to present a resistance to writing. Students' "failures" are often excessively focused on mistakes (e.g., incorrectly spelled words and need for their correction) to determine their progress, as well as an overvaluation of their written products concerning the writing process. These aspects compromise how the child comprehends his/her effectiveness in the writing tasks which may lead to the creation of resistance to these types of activities that compromise not only students' individual expression but also their ability to interpret the world around them.

Writing currently implies understanding both linear and multimodal writing and involves in-depth knowledge of the various contexts and situations of written communication, including the use of technologies. In a semiotic and multi-literacy perspective (Cope and Kalantzis 2000), writing assumes a multidimensional and dynamic nature that integrates the use of linguistic, visual, spatial, gestural, and audio characteristics, as well as the role of design (in production

and presentation), in the construction of textual meaning.

Children are receptive to the use of technologies in their lives, showing personal interest to explore these resources. A clear example of this situation arose in the school year 2015/2016 when 4th grade students of clusters of schools in the city of Braga (Portugal) answered that their jobs in the future will be YouTubers, some of whom had already started the process of publishing videos with the aid of their parents. Examples like these arise in various parts of the world (Araújo 2017). However, teachers do not always integrate the use of technologies in their classroom practices or think of new ways to promote meaningful and attractive learning techniques for children using technology, largely due to the lack of time, resources, and knowledge that makes them practical and simple to implement. Despite several constraints that may arise in the use of technologies in the classroom, the integration of these resources proves to be relevant since technologies are a powerful, interesting, and flexible tool, for example, to promote authentic and interesting writing tasks.

The promotion and improvement of students' writing performance and the early intervention of classroom writing problems are very important for students' lives, allowing them to be better able to interpret the messages around them and express themselves appropriately to others. The use of self-regulated strategies, combined with technologies in the classroom context, could also help students who struggle with writing to improve their performance.

In this sense, we will explore, throughout this entry, examples of how technological resources were integrated in 4th year classrooms in the city of Braga, Portugal, to promote the improvement of the writing performance of opinion essays, which proved to be effective for most students.

Self-Regulation and the SRSD Model in Learning Processes

Self-regulation is one of the most important capacities for human beings, allowing the body

and the different organs to manage the resources according to the needs, such as the maintenance of body temperature. The human body is prepared to perform regulation processes automatically; however when there is a failure in these processes, the body goes into imbalance which may have several negative effects.

Contrary to our body, the skill to self-regulate is not innate, and we need training, effort, and cognitive maturity to develop this ability and which can also be detrimental to our existence. We also need to learn how to control our behavior, emotions, and thinking in order to obtain our goals. This skill helps us to understanding what must be done to reach our goals and continuously assess how close or far we are to reaching that goal. Teachers can help their students to progressively improve their capacities to use self-regulation in order to achieve their personal or academic goals, for example, by improving their performance in writing opinion essays. Given the potentials of using self-regulation, students should begin to develop this competency in primary school.

Therefore, the SRSD model is the strongest intervention in writing based on scientific and practical evidence that uses self-regulation to promote students' improvement in writing capabilities, with recourse to goal setting and adjustments, self-instructions, self-monitoring, self-reinforcement, and metacognition. This explicit and flexible model includes six stages: (1) develop it; (2) discuss it; (3) model it; (4) memorize it; (5) support it; and (6) independence (Harris et al. 2008). The effects of this model on students have already been tested in different countries and in different contexts (e.g., large group, small group, or individual) and reveal very positive effects on the level of knowledge and attitudes in the writing process (e.g., motivation), perceptions of self-efficacy, and writing performance (presence of several writing elements for each type of essay, improvements in writing quality, use of linking words, and, often, improving the length of essays).

However, researchers have recognized that more and different research is needed, especially in the classroom context (Graham and Harris

2013). It should also be noted that the success of the implementation of evidence-based practice as is the case of the SRSD model is not guaranteed, although it is more likely to be successful, as it will largely depend on how it is implemented and the contexts in which it is implemented. For more information on the SRSD model see, for example, <http://www.thinksrsd.com/> or Harris et al. (2008).

Technology in the Writing Process

Several authors consider that the use of ICT during the writing process can be favorable to the quality of the text produced. In this way, during the planning process, the writer uses memory and/or external resources (e.g., research, observation, rewriting) to formulate ideas that can be integrated into the text and subsequently selected and organized. Also, the mobilization of strategies in the use of the broker spelling for text editing and the possibility of correcting errors without registration in the final version can be facilitated in the accomplishment of students' and teachers' goals during the textualization process (involving the transformation and development of ideas planned in the text) and the revision process (e.g., orthographic, syntactic, morphological correction, adjustment to the objectives). Finally, regarding publishing, it allows sharing on the Internet, with the increase of author-reader interaction or the possibility of network writing communities (e.g., collaborative and interactive).

The potentialities of the graphical possibilities of formation and production of the text (e.g., emoticons, multimedia, hypertext, multimodality), as well as allowing retroversion of actions, aid in the development of confidence creating conditions for the student to see the results (MacArthur 2009; Tavares and Barbeiro 2011). Also, students can "experiment" on the computer without leaving this *mark of error*, thus enabling the stimulation of learning experiences and technological fluency.

Investigations regarding the potentiality and relevance of the use of technological tools in writing have focused on the use of the word processor associated with the keyboard or the

spelling checker, as well as speech-to-text or text-to-speech software, especially in an individual context or in a small group (Thompson et al. 2016). Some of the scientific evidence of the support technologies used by students with learning difficulties at the writing level were the orthographic corrector, speech synthesizer (programs where speaking and writing software converted speech into text), text-to-speech systems (automatic speech recognition system that converts text to speech, using artificial speech) and the predictor of words (software that predicts the correct spelling of a word, as the writer types, taking into account the frequency and context of the words) (Peterson-Karlan 2011).

Therefore, the results confirm the benefits of the use of assistive technologies for the writing process of students with learning disabilities in writing, in terms of spelling, grammar, prewriting activities, and the delineation of ideas. The use of speech synthesizers or text recognizers is particularly useful for transcription and proofreading; however, these types of tools may not be suitable for activities in the classroom context because the program is not always able to read correctly what is written, which may be counterproductive to the learning/teaching process, or there is too much noise which can condition the correct writing of words by the software (Thompson et al. 2016).

Additionally, the use of web resources is beneficial in the writing process, since it facilitates immediate access to information, exploration of individual interests and/or clarification of real-time doubts, and stimulation of the exploration of diverse communicative spaces and acts as a stimulus to peer collaboration. Consequently, these are considered some of the advantages pointed out in the use of ICT resources, although it is also recognized that there exists some difficulty in analyzing, selecting, and treating the information collected. Also, the multimedia resources have allowed access to multiple forms of communication (e.g., text, sound, and image).

The applications of notepad and Smart pens have the potentials to help students with writing difficulties to compensate for the poor ability to take notes (e.g., reduced writing fluency, difficulty in selecting meaningful information, or difficulty

in understanding the meaning of notes after reading) which results in the difficulties experienced in the processing of information. Also, other features like the digital book and digital mind maps can ease the writing process of students (Araújo 2017; Tavares and Barbeiro 2011; Thompson et al. 2016).

As for multimodal writing, it was possible to verify the potentials of the multimodal use of technologies by supporting the development and modeling of strategies throughout the various stages of the writing process, namely, with writing, editing, and revision tools. For example, the capabilities of the word processor are far superior to that of paper and pencil, easy to understand and use, and allows for the adoption of text-to-speech applications that permit the reading aloud of essays written by students, as well as the use of the spelling checker or dictionary (Cuban 2001). In another study (Wolf et al. 2016), it was also found that the use of a multimodal intervention in writing (auditory, visual, tactile, and motor) proved to be more effective than manual writing, presenting better recognition of spelling errors in dictation.

Finally, several authors have reinforced the importance of studying the instructional design of using technologies to support instructions in writing, not forgetting that basic writing skills are also important (e.g., MacArthur 2009; Troia et al. 2012).

Classroom Intervention Using Technologies

Technologies are prevalent in society, both in and out of school (Graham and Hall 2016). The use of technologies in classroom interventions has demonstrated positive effects on the learning process and writing performance, as well as the students' learning process in general (Graham and Hall 2016; Morphy and Graham 2012). For its part, learning should promote the development of functional, critical, and active literacy skills with technologies (Buckingham 2007). Similarly, students with higher ICT skills will be more prepared for the future. It is also well-known that when

students control their learning, that is, they regulate technology, they produce better results than when it is the teacher who performs this role (Hattie 2009).

In this sense, the following presents some aspects considered relevant in the planning of writing activities in the context of the classroom, using ICT.

ICT Tools in the Classroom

Current technologies consist of powerful, interactive, and flexible tools for teaching and completing quality writing by students with and without specific learning difficulties (MacArthur 2009).

The use of spelling software, speech recognition, voice synthesizers, and word predictors can be beneficial to students' writing, especially those with learning disabilities (Thompson et al. 2016). The positive correlation between computer composition and quality, and extension and motivation for writing were also verified in some studies (Peterson and McClay 2012).

On the other hand, notepad applications and smart pens have the potential to assist students who have poor note-taking skills, increasing the accuracy and comprehension of the information read (Berninger et al. 2015). Also, the use of conceptual maps or graphic organizers has had positive effects in writing on students with learning disabilities and attention problems (e.g., *Coggle*, *Mindomo*, *iMindMap*). Similarly, the use of iPads among children aged 3 to 13 during the process of alphabetization or preliteracy was considered positive in increasing motivation and concentration and in the construction of rich environments in communication and collaborative interaction (Flewitt et al. 2014).

However, we cannot forget that, generally, the use of technologies is optional, as there are contexts such as the use of assistive technologies that, by themselves, overcome barriers imposed on learning and develop compensatory strategies (CAST 2011) and which should not be ignored or underestimated. Furthermore, the potentials of writing technologies, especially among students with writing problems or with learning disabilities, are also recognized (Thompson et al. 2016), but there are different perceptions and

discourses about school and sometimes contradictory technologies (Tavares and Barbeiro 2011). As a result, there is still a great deal of disorientation in how to implement classroom interventions that respect all students and take advantage of the potentials of these resources.

Approaches to ICT Use in the Classroom

Studies involving the use of technologies in primary school classrooms have found that teachers tend to use two distinct approaches: demonstration and practice and instruction (Akbiyik and Seferoglu 2012). However, several authors highlight the importance of providing instruction and individualized assistance in writing systematically (e.g., Graham et al. 2012). Thus, several authors advocate learning spaces, with planned practices, which include the use of multimedia and technology, which offer interesting, authentic, and purposeful writing tasks (Kellogg 2008). MacArthur (2009) points out that the most important thing is to study the instructional design of using technologies to support instruction in writing while not forgetting that basic writing skills are also important. This idea is also reinforced by other authors (e.g., Troia et al. 2012). Also, Smedt and Keer (2014) consider that ICT should be combined with instruction and collaborative practices to improve students' writing. Finally, pedagogical practices should follow clear, explicit, practical, scientifically validated, and teacher-guided instructions according to the individual needs of the students in the class and the goals to be attained (Boyle et al. 2015). However, more and better research on how technologies can be beneficial to students is needed, especially among students with learning disabilities, and involving the use of mobile devices (Berninger et al. 2015).

Context Knowledge for Classroom Intervention Using Technologies

The individual characteristics of students can positively or negatively influence the effectiveness of the use of technologies in the learning process of writing (Araújo 2017; MacArthur 2009) since the use of technologies alone does not guarantee a positive effect of these tools in the education process. One factor that may be determinant is

gender since it is known that male and female students tend to present different attitudes toward writing using technologies (Araújo 2017). Also, the presence of writing problems reveals that students present lower perceptions of self-efficacy and knowledge in writing and tend to present distorted perceptions of their writing abilities, considering them to be more positive than their real performance (Araújo 2017). Similarly, the writing practices of students in the classroom, with or without the experience of the use of technological resources, are important to understand the teachers' practice of using the technologies in the classroom (Araújo 2017; Culter and Graham 2008).

Knowledge, Attitudes, and Self-Efficacy in Writing with and Without Technologies

According to the research, the students tend to present, in general, perceptions about moderate writing knowledge but lower than the perceptions regarding their knowledge in writing using technologies (Araújo 2017). However, these aspects are not always considered in the design of interventions, although positive attitudes are related to greater commitment, involvement, and effort in the writing process (Tavares and Barbeiro 2011). In this context, it was found, for example, that in a descriptive study with students and teachers of the 4th year of schooling, the students' attitudes toward writing using technologies were more positive than attitudes to writing without technologies. Also, regarding students' perceptions of self-efficacy in writing, reduced values for writing without using technologies were observed, as well as using technologies, although with slightly more positive teacher perceptions of the use of technologies by students at home, focusing on the use of games, completing exercises, visualizing videos, and conducting research (Araújo 2017).

Motivation

Research has shown that motivation is a fundamental factor in the development of learning and, consequently, the quality of students' performance assuming themselves as powerful and interactive tools. In this entry, the motivational role of ICT in writing has been widely discussed by several researchers, but the truth of this

premise is not unanimous, and there is a need for further research on this subject (MacArthur 2009; Peterson-Karlan 2011; Troia et al. 2012). Despite this, it is important to mention that many researchers reinforce the presence of intrinsic and extrinsic (e.g., social) motivation to use these tools in the writing process (Lacina and Griffith 2012).

The Role of the SRSD and Technology in the Primary School Classroom Context

The operation of writing activities using self-regulated strategy development, and the use of technologies in a self-regulated way in the primary school classroom context to promote the improvement of the writing quality of students in the 4th grade, implies a reflection on how they could be integrated (e.g., writing goals, authentic writing contexts, dictation of students' texts, writing-reading relationships), together with ICT tools and resources, for the learning of writing (e.g., word processor, spelling checker, mental maps, speech synthesizers, and others) in the activities developed in a large group and in the school context. By applying the analysis and reflection of different theoretical perspectives on how to integrate technologies in this context, and based on research in scientific databases, we proceeded with the adaptation of the SRSD model, with the integration of technologies, and the exploration of linear and multimodal writing, in a preventive intervention context for writing problems (Araújo 2017; Fuchs et al. 2008).

The structural basis of the SRSD + ICT intervention was followed by the instructional design of the SRSD model, respecting all its principles, stages, and characteristics. It was then decided to opt for the sequential exploration of the teaching of analogical, linear writing, followed by the writing of texts in digital context, the use of associated tools, and later the exploration of multimodal writing. During the process, we explored aspects such as reading, writing, and comprehension of texts or image (e.g., identifying important issues, locating information, critically evaluating the usefulness of such information, synthesizing information to answer such questions) or social skills

of interaction, collaboration, and sharing (e.g., communicating the message and/or responses to other people).

Although digital technologies and contexts had been applied during writing activities, students were expected to explain and meaningfully explore different forms, contexts, and writing tools so that through their experiences, they were progressively able to select those resources that they considered useful for their writing process (see Fig. 1).

The SRSD + ICT model was constructed taking into account some aspects such as multi-based theories, highlighting some models that contributed to the construction of the design of this intervention, specifically:

- (a) All the principles, characteristics, and stages of the SRSD model (Harris et al. 2008).
- (b) Recourse to the different stages of the Revised Blooms' Taxonomy (Anderson and Krathwohl 2001), progressively increasing the complexity of the processes mobilized for the writing activities from the remembering to creating.
- (c) The use of the TPACK model (Graham 2011) which reinforces the need for the teacher to have knowledge about writing, the use of technologies and tools which can enhance the development of writing skills and also pedagogical knowledge on how to develop these types of activities with students

(e.g., in-depth knowledge of the writing process, teaching writing strategies, and methodologies, knowledge of useful tools and contexts and enhancers of writing activities, exploration of the various forms and contexts of writing).

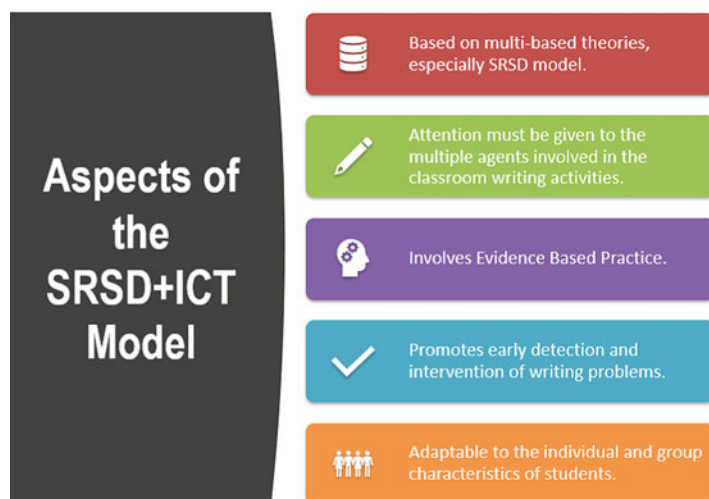
- (d) The use of some elements of the UDL model (Rose and Meyer 2002) with the exploration of the meaning diversity of the writing process; the exploration of multiple means of representations (e.g., auditory, visual, kinesthetic), effort, reinforcement, and persistence during the proposed tasks; and finally the role of self-regulation, interest, and ICT tools in the writing process.

Another aspect considered for the planning of interventions using the SRSD + ICT model, involving the use of technologies and digital media, necessarily implies having previous knowledge of the contexts and actors involved in the pedagogical activities of writing in the classroom. This knowledge implies understanding the knowledge, attitudes, and self-efficacy of students and teachers for writing texts, with and without the use of technologies, as well as knowledge of the use of technology and writing in and out of the classroom.

The SRSD + ICT also integrates aspects such as the involvement of evidence-based practices during the intervention in order to promote the development of functional, critical, and active

Exploratory Study Using Self-Regulated Self-Development (SRSD) and Technology in the Context of the Classroom,

Fig. 1 Aspects of the SRSD+ ICT model



skills of writing with and without the technologies that allow early detection and intervention in student's writing problems and seeks to adjust the activities to the individual and group characteristics of the class.

The inclusion of the use of ICT tools, throughout the implementation in the process, follows these steps: (a) the presentation of tools and some of the potentialities for writing, (b) discussion with students, and (c) modeling the use of tools in text production.

In this way, this research endeavored to analyze the impact of the SRSD + ICT model on students' opinion essay writing performance, through the inclusion and exploration of how and when students could or should use ICT during the writing process, and the promotion of innovative learning practices with technologies (Figs. 2 and 3).

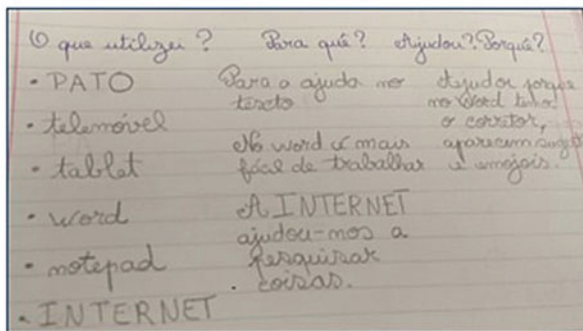
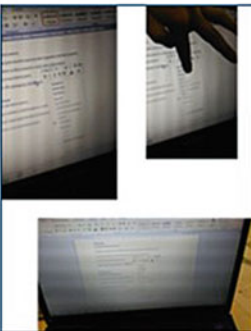
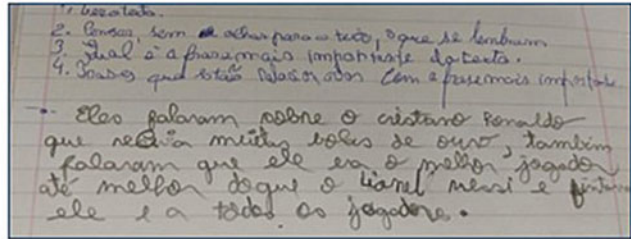
Example of Primary Classroom Intervention with Technologies

As an example, an exploratory study that sought to analyze the impact of this intervention (SRSD + ICT) in 82 4th grade students' performance of

writing opinion essays, after 12 weeks of instruction (90 min/week) in Braga, Portugal, verified that positive results occurred in students' opinion essay writing performance, quality, essay length, and number of linking words (Fig. 4).

The effect size of the intervention was $d = 2.97$ in writing elements, $d = 3.55$ in quality of text, $d = 0.27$ in length of text, and $d = 2$ in number of linking words. The results also reinforced the positive effects of ICT in students' writing process, already evidenced in previous studies (for more information, please see Araújo 2017).

The fact that the SRSD + ICT intervention model presented here has obtained even more positive results than those previously observed with the SRSD model, which is considered the strongest model in writing intervention, as well as the use of evidence-based practices for writing combined with self-regulating ICT use in the writing process, underlines the importance of discussing how ICT can contribute to supporting students' writing learning. It also analyzes how the SRSD model with ICT can be a positive factor in improving students' writing performance, reintegrating the importance of the transversal use of a self-regulated process to the

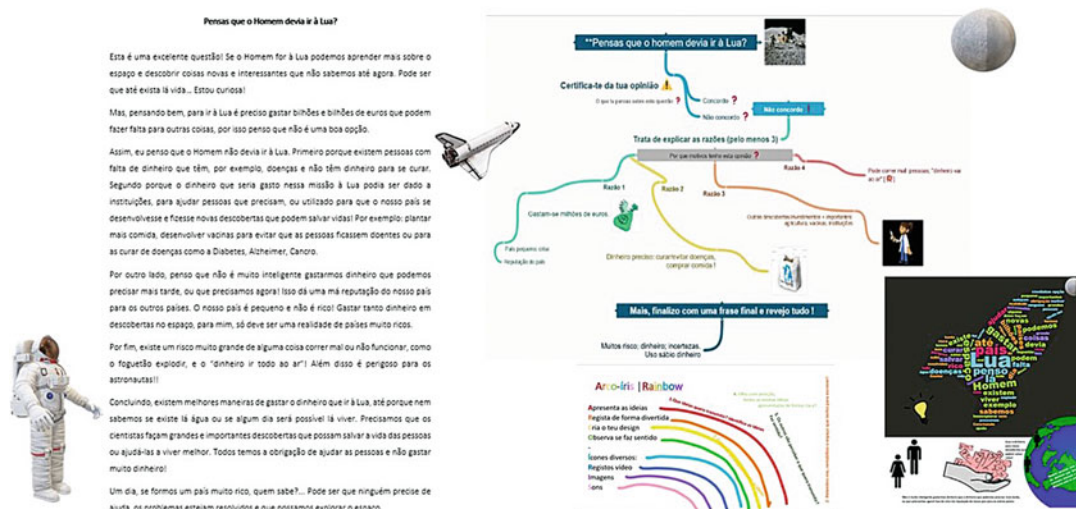


Exploratory Study Using Self-Regulated Self-Development (SRSD) and Technology in the Context of the Classroom, Fig. 2 Examples of the writing process

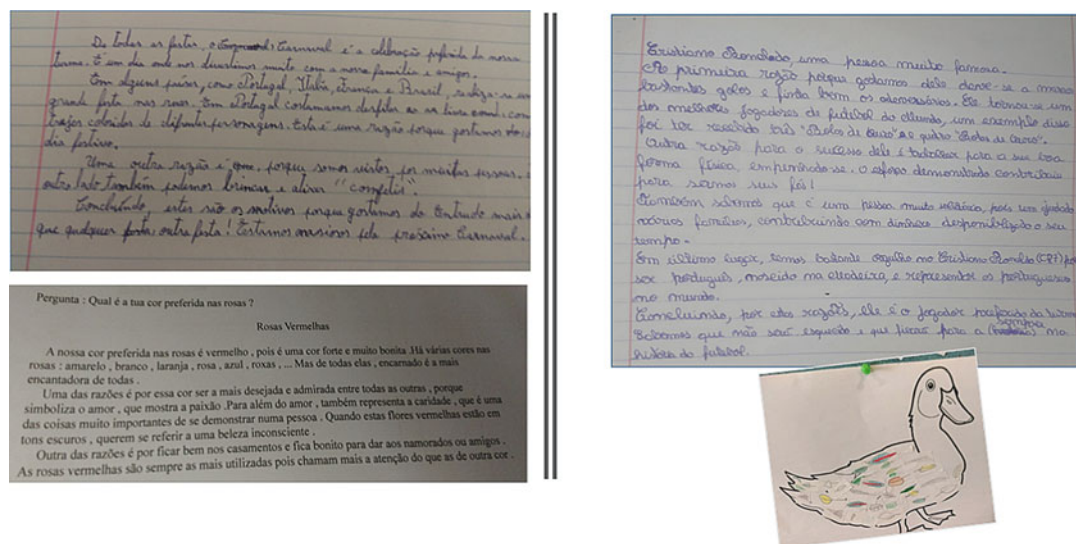
different learning contexts. As a result, the role of this model with respect to individual students' needs is also highlighted.

However, although it is impossible to understand which elements contributed the most to the results, we found that the students improved their performance in writing essays through the described processes, stages, and moments of

evaluation. The progressive, explicit, flexible, and accompanied exploration process allowed students to understand and progressively apply the strategies learned, by mobilizing them during their text production processes, either collaboratively or in groups. The exploration of different forms, formats, and resources seems to have provided students with moments of reflection about



Exploratory Study Using Self-Regulated Self-Development (SRSD) and Technology in the Context of the Classroom, Fig. 3 Examples of applied resources



Exploratory Study Using Self-Regulated Self-Development (SRSD) and Technology in the Context of the Classroom, Fig. 4 Examples of the writing tasks produced by students

the various stages of the writing process in different contexts, what goals need to be applied, what they are expected to achieve, and how to achieve those goals. The knowledge acquired by the students in their use of technologies, and the testing of tools or resources, always allowed students to use the technologies but only when they were useful in the course of their writing process. What they learned from the exploitation of the writing process, in different contexts and situations, seems to have increased the awareness of the writing process that was reflected not only in texts produced in digital format but especially in analog format.

Conclusions and Implications

Some research data can assist teachers in designing writing activities in the classroom context with ICT resources. However, the success of interventions for the development of competencies and student performance will largely depend on the characteristics of the students and contexts in which they are inserted, as well as on the options of teachers in the strategies and learning methodologies.

It was also verified that on the one hand, allowing students to know explicitly the potentials of ICT resources throughout the writing process can have positive effects on their performance. On the other hand, the possibility of reflecting, experiencing, and deciding, with the help of the teacher, what resources are useful in the learning process not only increases students' knowledge about themselves and about the resources that surround them but also allows them to value their opinions and perceptions about the learning process.

It should also be noted that several authors in this area reinforce the pertinence of carrying out activities alternating between working in a large group, small group, and individually, allowing the construction of specific workspaces according to established objectives that respect the needs of the group and each student. They also allow a stimulus to collaboration, sharing, and creativity among mutually supportive students.

Also, the possibility of operating several theoretical recommendations for pedagogical practice

was evident together with the promotion of early detection and intervention of writing problems both individually and in groups. However, it also focuses intervention on the individual and the adjustability to the characteristics and needs of students.

The SRSD + ICT model, for example, with the integration of technologies in the classroom, also allows teachers to integrate the SRSD model associated with PBE and technologies, in preventive models in the classroom context, in order to promote and outline early identification, intervention, and assessment strategies to address the disadvantaged situations that students may present. When implementing this model, teachers should therefore consider the influence of perceptions and type of practices in the classroom in the teaching-learning process and listen more to students' options in their classrooms. Teachers should also encourage the profitability and integration of the technological resources of the families in the pedagogical practices of their classroom.

Finally, it is also considered fundamental to continuously and transversally promote the use of the processes of self-regulation in learning and to promote changes in writing practice in the classroom by approaching different forms and writing formats.

However, further studies need to be performed to reiterate or not the positive results obtained in this intervention, such as exploring different contexts (e.g., linguistic, cultural, educational level). Yet, these examples of integration of different elements and strategies to support the development of the writing of essays in the classroom context have allowed us to understand that it is possible to use technologies in the learning process of writing and understand the contexts and take advantage of the resources of the students' families.

Cross-References

- ▶ [Assistive Technology and Inclusion, Philosophical Foundation](#)
- ▶ [Literacy and Technology](#)
- ▶ [Teacher Education, Thinking About ICT](#)
- ▶ [Technology Enhanced Learning](#)

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Extranet

► [Ultranet](#)

eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding

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Synonyms

[Change management](#); [Computational thinking](#); [Continuous development](#); [DevOps](#); [Formal models](#); [Low code development environments](#); [Model driven design](#); [Service-oriented computing](#); [Software evolution](#); [Tools and platforms](#); [XMDD](#)

Introduction

This entry presents the eXtreme Model-Driven Development approach as a low-code approach to collaborative application design and development that uses formal, executable models as the central asset for the prototype-based design and development. It introduces the concept and practice of low-code approaches in section “[Low-Code Application Development](#),” in particular its potential as a large-scale paradigm for future IT. It then introduces XMDD in sections “[XMDD: eXtreme Model-Driven Development](#)” and “[Experience in the Educational Context](#)”; it summarizes over a decade of teaching and learning experience at different levels, on different aspects of software design, and with different tools. It then discusses some aspects relevant to the educational and the adoption context (section “[Discussion](#)”). Section “[Conclusions](#)” concludes the entry with a summary and perspectives for the future.

Low-Code Application Development

Low-code application development environments are gaining attention in industry. Gartner reports as their Strategic Planning Assumptions that “by 2024, three-quarters of large enterprises will be using at least four low-code development tools for both IT application development and citizen development initiatives”, and “by 2024, low-code application development will be responsible for more than 65% of application development activity” (Vincent et al. [2019](#)).

Traditional application platforms provide runtime environments for application logic. They manage the life cycle of an application or application component, and ensure the availability, reliability, scalability, security, and monitoring of application logic.

A **low-code application platform (LCAP)** is an application platform that supports rapid application development, one-step deployment, execution, and management **using declarative, high-level programming abstractions, such as model-driven and metadata-based programming languages**. They support the development

of user interfaces, business logic and data services, and improve productivity at the expense of portability across vendors, as compared with conventional application platforms (Vincent et al. 2019).

Why Not in Education?

Low-code and no-code software design are not yet part of the standard curricula in schools or third-level education. The many reasons reflecting the beliefs of current educators can be summarized in three main theses:

1. Coding in **3G languages** is the state of the art in industry, thus it is what best trains students to be profession-ready today.
2. The **models** used in low-code environments may be more distant from “real code” (i.e., handwritten or hand-assembled code). Thus, they need substantial checks and post processing additional to the usual code-level quality assurance.
3. The more **formal models** adopted by some of these environments are mathematically underpinned, thus inherently difficult, and should be relegated to specialized training, like elective courses or a postgraduate level.

The cited assumptions in the recent Gartner study counters the first thesis: If a majority of enterprises is deemed ready to adopt this new trend in the next 5 years, these skills, methods, and tools are immediately relevant to educators in secondary school and third-level programs; their pipeline is in fact typically 3–5 years, and students should be prepared for the design culture and tool landscape, they will be asked to master upon graduation.

The model distance argument is a generational matter. Not long ago, 4GL like SQL and 3GL programming languages like C, C#, and Java were considered “too abstract” and “not controlling enough” by cohorts of programmers trained to believe that handmade byte or address level memory management is essential. Even within the 3GL cohort, the discussion about the “true need” and portability advantage versus inefficiency due to interpretation and inherent risk (thus the sandbox

concept) brought by the move towards virtual machines has pitted C++ supporters against Java adopters. Yet SQL and C/C++ are taught since 1980s, and Java became a prevailing standard in education in 1990s. The reason for their success and adoption in education and industry alike was a new kind of “simplification.” The essence of this simplification was a separation of concerns between a more declarative “what” (expressed in the SQL query, the Java program) and the more technical and detailed “how” connected with its execution. In the case of SQL, it was the database storage level organization, or the query computation. In the case of Java, it was the platform-specific virtual machine, mapping the bytecode to the specific instruction set and memory management practice of the target computational platform.

Significantly, the next educational waves have seen a split between a fail-fast approach geared to rapid prototyping, and model-driven but descriptive approaches à la UML (Unified Modelling Language) (UML 2.5.1 specification 2017) that focus on a better design prior to coding.

The rapid prototyping wing led to the popularity of script-like, interpreted textual languages like Perl, Python, Ruby, and Javascript. The traditional model-driven community developed tools with a graphical syntax, aimed at a spatial, visual, and standardized representation of entities, their many relations, but with no or limited execution capabilities.

As a consequence, standard curricula today predominantly adopt one of the 3GL languages as the learning basis for programming and its practice, provide instruction in one or more additional languages to address other paradigms (e.g., imperative, object-oriented, logic, functional), add some subset of UML to deal mostly with the static architecture (class diagrams, usually compared to ER diagrams) and some aspects of behaviors (sequence charts, state charts), topped by some other language for specific domains, like SQL for databases or XML-like languages for user interface design. These are seen as Domain-Specific languages, distinct from the core programming languages and thus heterogeneous, and in need of manual “bridging” or integration. One of the classic examples is the

Object-relational mapping (ORM) needed to translate between the classes of an object-oriented language and the relational entities in a database schema. Formal models are usually relegated to the theory modules, e.g., various kinds of automata, and data structures like trees and graphs, usually used in the classes that involve algorithms. Low code and no code are not foreseen.

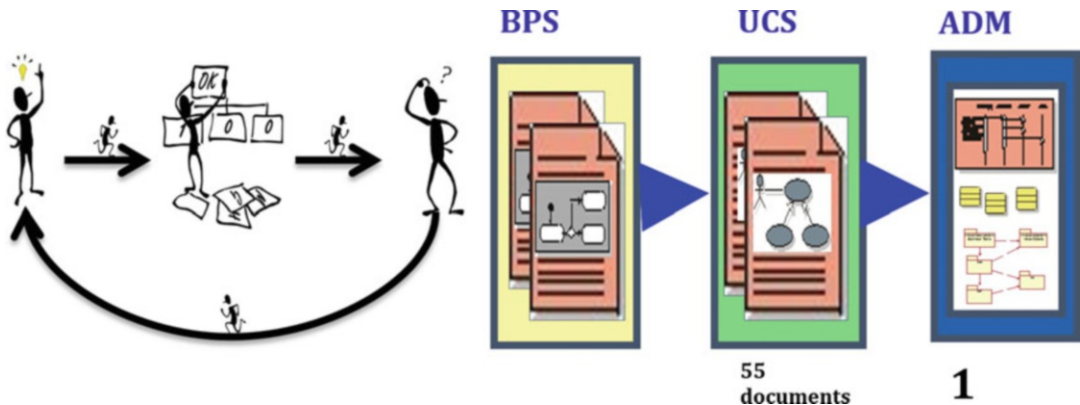
Low Code as the Paradigm for Future IT

The reality of the Digital Transformation in the global society is such that not just the professional programmers need to master application development, but increasingly large segments of professionals in every domain of industry and society. There is an increasing pressure of Industry 4.0 and its pervasive digitalization in manufacturing and engineering, the increasing footprint of healthcare integration and digitalization, the connected health, smart aging, smart agriculture, smart cities, as well as the citizen developer initiatives sprouting locally, nationally, and globally. The software needed to deliver all this will have to be designed, co-developed, and evolved largely by individuals that are professionals in some domain area, but not trained to program in today's prevailing notion of programming.

The future IT will be more softwarized, as it happened with Software Defined Networks in the telecommunication industry and is currently happening with the Digital Twin in manufacturing.

Therefore, the future society needs an affordable yet precise and technically advanced solution to mass production of bespoke applications by professionals knowledgeable in their subject matter, who know “what” they need. They need affordable technical means to express with sufficient precision how these applications should work. Classical textual requirement engineering is not a good option: text fragments have too much distance from the running system. The prototype culture and the co-development approach promoted by XP, the eXtreme Programming movement (Beck and Andres 2004) were successful in fostering the collaborative approach between programmers and “customers,” but the hurdle of the cryptic code as the primary means of application creation still excluded the non-coders, the vast majority is of professionals. The situation depicted in Fig. 1 (left), where experts have to guess based on a large number of textual artifacts (right) that are handed over from one kind of expert to the next.

Figure 1 is taken from a project that followed the Rational Unified Process (Kruchten 2004): in RUP, many heterogeneous textual process descriptions, use case diagrams, and other UML diagrams are all aggregated in one single architectural model that is expected to embody all their imposed constraints on the eventual solution. This is hard to achieve and impossible to check, both at the design stage and on the implementation, which is a distinct collection of hand-programmed artifacts.



eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding, Fig. 1 Mainstream approach

(left) with different types and collections of documents (right) – based on the Rational Unified Process (RUP)

Low code based on **executable models** is the combined paradigm that can deliver a design and development approach that is intelligible to the professionals, prototype based, and designed to master evolution and change.

The key elements of this low-code paradigm are the use of **models** instead of code, and the use of models that are **formal, integrated, and executable**. This is the XMDD approach.

XMDD: eXtreme Model-Driven Development

XMDD (eXtreme Model-Driven Design) (Margaria and Steffen 2008, 2009a) joins the best aspects of several successful trends (service orientation, aspect orientation, model-driven development, agility, eXtreme programming, generative programming, and full code generation) in modern software engineering for a *Continuous Model-Driven Engineering* (Margaria and Steffen 2009b) approach to the design of complex software systems. Its central artifacts are **models** that are **executable** and **formal**, i.e., mathematically underpinned.

Participation: Experts that Co-design

As a method, *Continuous Model-Driven Engineering* focusses on **consistent dialogue** of all involved stakeholders. This has two aspects: the systematic dialogue and its systematic consistency. The dialogue is possible due to the specific choice of models that are understandable by the application domain experts, the technical experts, and the programmers responsible for the implementation.

As sketched in Fig. 2, the entire development process is a cooperative, hierarchical, and interactive decision process where all the experts, including the programmers, collaboratively build and refine **one comprehensive model**. With the XMDD approach, the prototype arises directly from the executable models, which are implemented in a service-oriented way using service-oriented technology, or similar abstraction mechanisms for APIs and libraries. Because the models are formal, in this case specifically Kripke

Transition Systems (KTS) (Müller-Olm et al. 1999), the models can be analyzed with algorithms, for example, with model checkers (Clarke et al. 1999) and even constructed by algorithms, as in process synthesis approaches (Steffen et al. 1993; Margaria and Steffen 1998; van der Aalst et al. 2004).

This formality is essential to ensure consistency: The algorithmic analysis on the models reveals inconsistencies in a timely fashion and exposes misunderstandings well before the system component or the entire system are fully coded and tested. With the progress of the design and the decisions, the method leads to a natural incremental formalization (Steffen et al. 1996a). This formalization is in terms of models and properties: it helps collect, share, and evaluate the discovered change needs and their amendments as soon as they arise and to materialize them in reusable services, features, and properties.

Benefit: Coherence and Consistency by Design

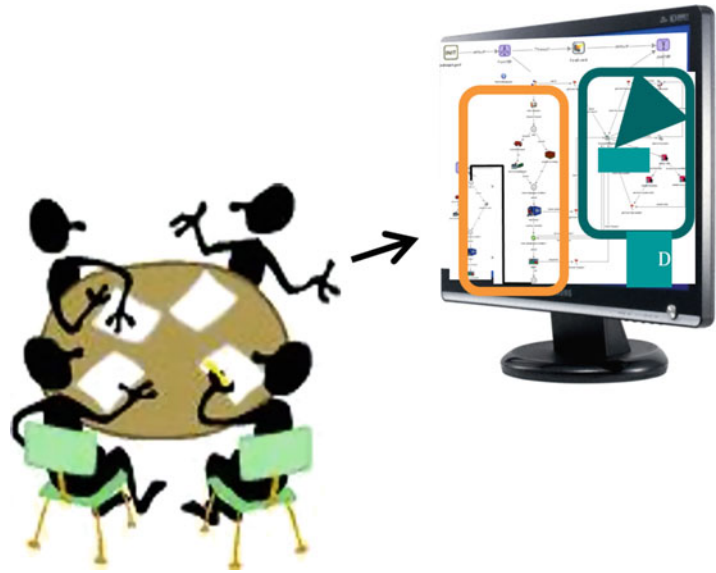
As a low-code technology, XMDD enables each stakeholder – including application domain experts that cannot program – to continuously express requirements or decisions in terms of constraints on the models. Each development step or evolution step is a transformation of the models or a reification of the constraint set, which typically comprises many aspects and touches on several forms of knowledge.

Like in **model-driven design**, XMDD uses models. They are, however, also *formal*, thus mathematically analyzable, *loose* (Naujokat et al. 2012) to enable refinement; *executable*, to enable immediate prototyping and execution; and *semantic*, to enable reasoning within a specific knowledge or application domain.

Like in **service-oriented computing**, XMDD makes use of collections of pre-programmed and potentially externally hosted functionalities. APIs, instruction sets, web services, and traditional code libraries have been transformed into *native Domain Specific Libraries*, with representations at the model level. As shown, for example, in Jörges et al. (2007), Margaria and Schieweck (2019) in robotics, in Niese et al. (2001) in telecommunications, in Lamprecht et al. (2008),

eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding,

Fig. 2 Continuous model-driven engineering in practice: the one thing approach with XMDD



Margaria et al. (2006) in bioinformatics, and in Airò Farulla et al. (2016) in security, they can be included as artifacts in the models, which are built bottom-up from GUI DSLs, collections of generic services, and these domain-specific collections.

Like in **eXtreme Programming**, XMDD welcomes essentially the participation by all stakeholders. Other than in XP, because XMDD is consistently low-code, nonprogrammers are able to work themselves with the models and the constraints, on par with the programmers.

Like in **Aspect-oriented approaches**, entire aspects are considered and dealt with separately from the design of the functionality. However, XMDD is not restricted to weaving as an aspect design and injection mechanism. For example, in DIME (Bosselmann et al. 2016), one of the recent XMDD implementations, roles, rights, and access policies are devoted an own model type and the weaving happens by compilation. Concerning security (Gossen et al. 2017, 2019) show that the insertion points where to inject the security-implementing code are kept implicit, basically every read and write needs to be adequately protected and the security-injecting compiler there described “knows” where and what to inject. The security aspect code is low-code itself.

Like in **Business Process Modeling**, another member of the low-code family, the main models in XMDD are processes. Called workflows in

scientific computing (entry ▶ “**Modeling of Scientific Workflows**” by Margaria and Lamprecht, this volume; Lamprecht et al. 2016a) or Service Logic Graphs in the telecommunication domain (Steffen et al. 1996b), the choice of the business logic as the main view central to the comprehension of the “story” behind an application or inside a hierarchical model is central to XMDD. Other than the popular datable models, Petri nets, or state charts, this approach adopt essentially activity diagram like models. The reason is that in order to understand what happens in one of those *insider*-oriented models, the user needs to master complex concepts like parallelism and the internal details of a system, essential for the notion of state, while this approach addresses stakeholders that are mostly *outsiders*, as in a truly service-oriented approach.

Continuous Evolution and Change Management

Knowledge, regulations, and various properties and constraints are adequately expressed in the following terms:

- **Properties** express the application’s intentions, internal policies, legal constraints, or technical frame conditions; they are typically formulated in logic, e.g., temporal logic for the workflow behaviors.

- **Loose process models** specify the rough distributed workflow from the management perspective, without concern for technicalities like type correctness, location, or interoperability that are taken care of elsewhere at a more technical level.
- **Symbolic type** information of services, processes, and data, sufficient to imply executability and enforced later by checking and synthesis technology
- Definitions of **roles and rights, timing and localization constraints, security, and exception handling**, which are integrated during aspect-oriented code generation.

The outcome is a methodology and toolset that delivers a simple and rigorous approach to managing changes, therefore continuous evolution and adaptation. It also delivers the integrated information and communication, and collaboration of heterogeneous roles and experts in a product management lifecycle as required by the increasingly popular DevOps integration. This happens through.

1. **Application-level control**, i.e., the continuous involvement of the customer and application expert along the entire systems' life cycle, including software maintenance and evolution
2. Continuous and ongoing **quality assurance** with different means at different levels and phases (requirement validation, simulation, model checking, data flow analysis, testing, and monitoring)
3. Specific support when **integrating** new technologies, services, or APIs, in a service-oriented way.

This way, XMDD significantly shortens the systems development lifecycle and it enables continuous delivery with high software quality.

Experience in the Educational Context

In practice, XMDD has revealed its power in the context of over 10 years of practice-based education and training. It was adopted in project-based courses, short trainings like Summer camps for

pupils or Summer schools for PhD students, to introduce formal methods-based concepts to software engineers, and to first-year students as a computational thinking scaffold to traditional programming.

The Models

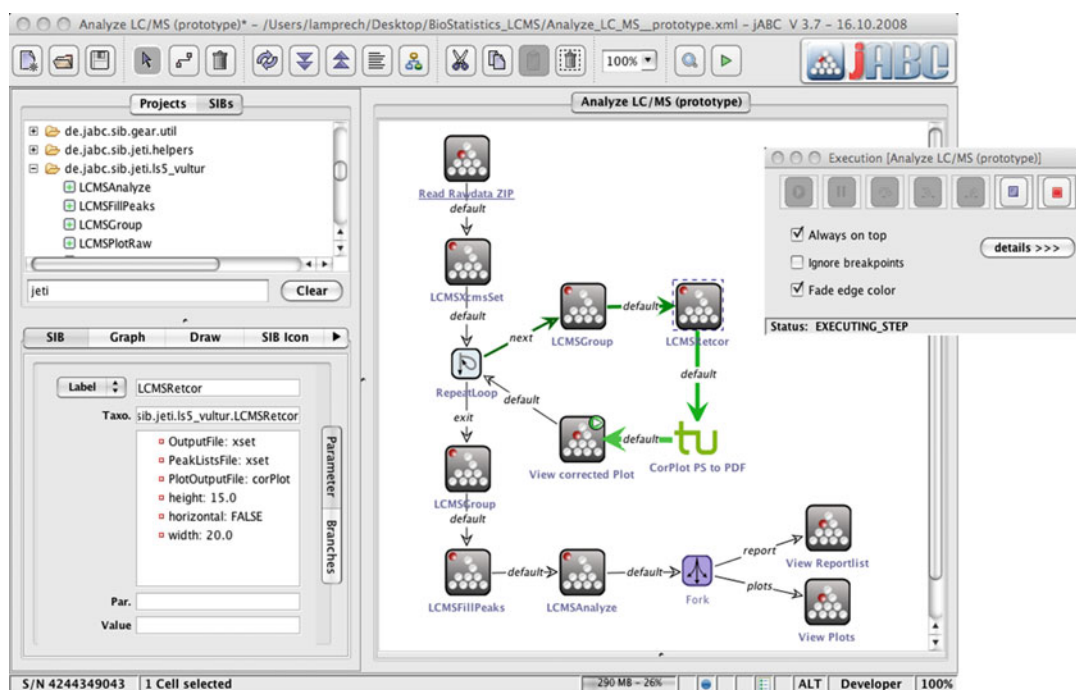
The Service Logic Graphs (SLGs) are a behavioral counterpart to the SCA (Service Composition Architecture (Curbera 2007; OASIS: Service Component Architecture Website 2019) composites, and they are architecturally compliant with the standard for Service Composition (Jung et al. 2008). As shown in Fig. 3, jABC users develop services and applications by graphically composing and configuring reusable building blocks into (flow-) graph structures. The reusable building blocks are the basic functionalities of a service-oriented DSL.

These basic building blocks were called SIBs (Service Independent Building Block) in jABC, in analogy to the original naming of elementary telecommunication services (see (Margaria et al. 2005a; Magedanz et al. 2007)). SIBs have one or more outgoing edges (branches), which depend on the different outcomes of the execution of their functionality. The resulting models, that orchestrate SIBs, are called Service Logic Graphs (SLGs). The terminology used in the SIB libraries and in the SLGs is tailored towards the considered target user group, typically the experts of the current application domain, without requiring any IT knowledge. Thus, they are adequate to represent the behavior of a service to business developers, customers, end users, and any beginners in the realm of IT.

The Tools and Platforms

As shown in Fig. 4, over the last 15 years were developed: primarily three XMDD platforms: jABC, Cinco, and DIME.

The jABC tool was developed in Java since 2003 and applied in numerous industrial and scientific projects (Bajohr and Margaria 2005; Hörmann et al. 2008; Margaria and Karusseit 2002; Neubauer et al. 2013). Driving forces for the further development were the scientific workflow projects reported in more detail in the entry ► “Modeling of Scientific Workflows” by



eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding, Fig. 3 Model and its execution in jABC 3. (From Kubczak et al. (2006))

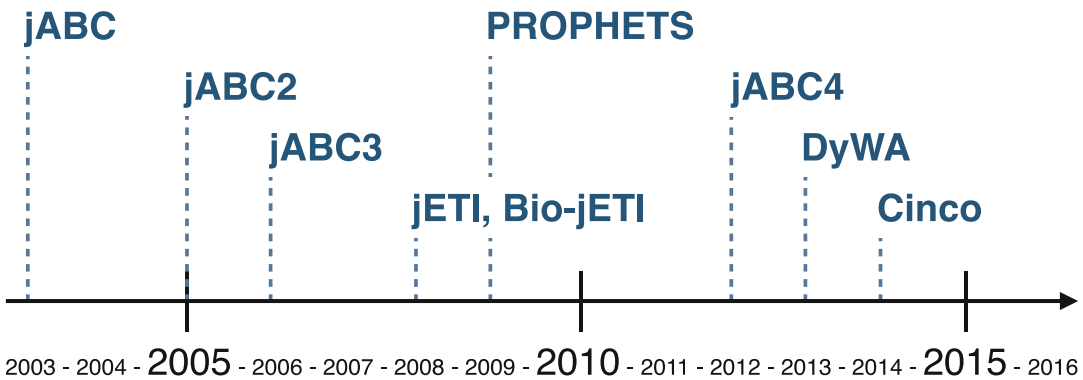
Margaria and Lamprecht, this volume). In parallel, the framework formed the backbone for numerous extensions, like the Electronic Tool Integration platform ETI (Steffen et al. 1997) and its variant jETI (Margaria et al. 2005b), the Genesys (Jörges 2013; Jörges et al. 2008), and PROPHETS (Process Realization and Optimization Platform using Human-readable Expressions of Temporal-logic Synthesis) (Lamprecht et al. 2010) plugins for code generation and model synthesis, and finally the DyWa tool for developing dynamic Web applications (Neubauer et al. 2014). Currently, the jABC heritage of designing domain-specific modelling tools is taken over by the Cinco Meta-tooling suite (Naujokat et al. 2018), which lifts domain modelling to the meta level.

jABC3

In particular, jABC3 provided since 2006 a very stable platform to work with application-level tracing and simulation models that are conveniently executable. Figure 1 gives an impression

of jABC3 in action, using an example workflow from a project on LC-MS data preprocessing and analysis (Kubczak et al. 2006). The SLG on the canvas has been created using SIBs from the service library (displayed in the upper left of the window) in a drag and drop fashion, and connecting them with labelled branches representing the flow of control. As soon as the parameters of the SIBs have been configured (in the SIB inspector at the lower left), the workflow is ready for execution. The small window in the upper right corner of the figure is the control panel of the Tracer plugin. In the picture, the Tracer window indicates that it is currently executing a SIB, and the green-colored branches of the model on the canvas visualize the current execution point and the path it followed.

The jABC3 release provided the core framework and the corresponding editor as graphical user interface, as shown in Fig. 1, but also a wealth of further features and capabilities for supporting workflow development that became available over the years:



eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding, Fig. 4 Chronology of the

XMDD family of tools from jABC to Cinco. (Adapted from Lamprecht et al. (2016a))

- The **GEAR model checking** plugin (Bakera et al. 2009) for model-wide verification of properties
- The **Genesys code generation** plugin (Jörges 2013; Jörges et al. 2008).
- The **IconEditor** for easy manipulation of SIB icons within the jABC GUI
- The **Layouter** plugin, which supports the automatic layout of larger SLGs,
- The **LocalChecker** plugin that can check defined properties of individual SIBs
- The **SIBCreator** plugin that can be used by work-flow designers to create code skeletons for new SIBs which are implemented later
- The **TaxonomyEditor** plugin, with which a collection of SIBs can be renamed and (re) arranged in a hierarchy of categories in order to optimally fit the domain structure
- The **Tracer** plugin as the inbuilt interpreter for SLGs that allows for their immediate execution

and two demo projects (a simplified web shop and a Turtle Graphics process project) designed to provide easy-to-follow examples and starting points for novice users.

jABC3 was successfully used in a number of industrial projects spanning telecommunication services, supply chain management, bio- and geo-informatics, logistics, automation, robotics, and health care. In all these cases, agility at the

customer, user, and application level was the key feature for success.

The projects often also made use of the associated jETI (Electronic Tool Integration) platform (Margaria et al. 2005b) to ease the integration of third-party tools as services for use within the jABC workflow framework. Initially predominantly adopted in the field of bioinformatics, where a domain-specific incarnation of the framework called Bio-jETI was established, applications of jABC soon emerged also in further scientific domains, such as geoinformatics and medical research (see, e.g., Al-areqi et al. (2014) and Lamprecht (2014)).

Cinco: Generating Tailored Frameworks

Cinco is a framework for the model-driven development of graphical modelling tools. It can be used for the automatic generation of a wide range of graphical modelling tools, as shown in Naujokat et al. (2014) for modelling concurrent systems.

On the one hand, it is used to develop XMDD modelling environments (like DIME (Bosselmann et al. 2016), WebStory (Lybecait et al. 2018), or AdventureGame (Gossen et al. 2018)), which all are regularly used in teaching.

On the other hand, it follows itself the XMDD approach. This means that the graphical modeling tools developed with Cinco, like DIME and the ones mentioned above, are actually not hand-

programmed but instead modelled in an abstract high-level specification and then code-generated into fully functional modelling environments, in a pure low-code approach.

The Cinco SCCE Meta Tooling Suite (<http://cinco.scce.info>) provides a generator-driven development environment for domain-specific graphical modelling tools that form the next generation of XMDD frameworks. The point of Cinco and the generated Cinco-products is to support a much broader use context envisaged for the design and modelling tools: Service-Centered Continuous Engineering (<http://scce.info>). SCCE extends the continuous design and continuous deployment of (Ståhl and Bosch 2014) to a continuous lifecycle support paradigm where users co-define and comanage the design and the evolution of deployed systems. This approach requires the coherent support of different levels of expertise and different concerns among the cooperating participants, and thus requires adaptability also of the technological means, including the design environment (like the jABC) itself.

In fact, one can observe that the more a software framework is tailored to a specific domain or even application, the easier is its uptake especially by non-CS user communities. Thus, Cinco's capability to generate the entire low-code design, development, and, in future also, deployment will open these technologies to a much broader audience. The approach is to tailor also the development tools to the application domain and the expertise of the users. Cinco goes further than the provision of suitable domain-specific service libraries by directly hooking onto domain-specific practices, conventions, and individual preferences for workflow or process modelling.

In the reported experience, using XMDD tools is generally well understood by students (graduates as well as undergraduates). Thus, developing business/application logic using a pre-defined library of service-oriented components (SIBs) proves to be quite intuitive. The same applies on the meta level when using Cinco-level services (such as meta plug-ins for "code generation" or "validation") for the development of their domain-specific modeling tools.

Developing XMDD tools seems instead more difficult. Here, students regularly struggle with the inclusion of SIB-like concepts into their DSLs. While not much can be done to lower the inherent complexity of the (meta-level) concepts, as many technical hurdles as possible are being successively removed from the Cinco framework. Cinco already has a concept for building tools with component libraries via an inter-model linking feature called "prime references," and in the future this feature will be extended by supporting efficient browsing/searching for components in such libraries, and simplifying the development of components with parameters, as was done for the inputs/outputs of SIBs in jABC and DIME.

DIME

DIME can be regarded as the Cinco-generated version of jABC; however, it is already tailored for the generation of tools that run in a browser. The experiences from three project group and five MSc theses in TU Dortmund matches very closely that with the jABC.

The Courses

Learning Modelling

Student projects/coursework in the Masters in Bioinformatics and Geo-visualization(86): Since 2008, the meanwhile mature jABC3 had also been an education tool. It was used to teach a variety of university courses on process modelling and service-based software development in the field of scientific work-flows to Bachelor and Master students of Computer Science and related disciplines, such as Business Informatics, Geo-visualization, and Bioinformatics. Although the students came with extremely different levels of prior knowledge in programming and software engineering – ranging from complete novices to experienced developers – they could even-handedly participate in the interdisciplinary oriented courses. By the end of 2015, more than 200 students had attended the courses, and accordingly the approach has been validated in both research and education environments. Detailed experience reports about the courses are

available in entry ► “[Modeling of Scientific Workflows](#)” by Margaria and Lamprecht, this volume, Lamprecht et al. (2016a), and Lamprecht (2014) for natural science, and in Gossen et al. (2018), Lamprecht et al. (2015), and Bordihn et al. (2015) for software engineering and introductory programs to Computer Science and programming. It is also used in connection with games as a low-threshold approach to teach Computational Thinking and the logic of programming constructs to various kinds of beginners as reported in entry ► “[Modeling of Games and Game Strategies](#)” by Margaria and Lamprecht, this volume as well as in Gossen et al. (2018), Lamprecht et al. (2016b), and McInerney et al. (2017).

As soon as the modules on Introduction to Computer Science at the University of Potsdam moved to a significant Problem-Based Learning component, for a number of years the student projects comprised lectures and laboratories on XMDD-based process modelling, followed by individual projects carried out with jABC3. Already in 2015, this collection comprised 86 scientific workflow projects, 34 of which were bioinformatics applications, 37 were from the geoinformatics domain, and 15 realized other kinds of scientific analysis processes. The students could not program. Instead, they used prepared native DSLs of the application domain. The projects were not predefined by the lecturers but proposed by the students themselves. Having already graduated in a natural science discipline or being advanced undergraduates, they were able to identify and tackle a reasonable data analysis problem from their respective domain. Thus, even if the scope of these projects was limited due to the time and resources available, they provide representative examples of scientific workflows created in a low-code development environment by application domain experts who cannot program in the traditional sense.

Learning (Regression) Testing and Model Learning In **testing** and in particular regression testing, given a product and a new candidate release, validate that the new release still supports the vital features of its predecessor. This model-

based approach allows here to go beyond the classical approach, where the test executions of the two releases are required to match precisely. Overcoming this original restriction helped to drastically reduce the number of irrelevant test failures.

In **model learning**, given an executable system together with an interface for remote execution, corresponding behavioral model are automatically inferred via testing. This feature is invaluable whenever one attempts to integrate third party/legacy components, or to discover a posteriori the effects of some customization on known systems.

Specifically addressing testing and testing-based model recovery, since 5 years automata learning (Isberner and Howar 2014; Steffen et al. 2011) based on low-code applications of XMDD has been used in the project-oriented course Web Technologies II at TU Dortmund. Automata learning has been taught as a means to establish a bridge between classical Web development and model-based thinking.

In the first years, only 20–30% of the 80–60 students taking the course every year were able to integrate this technology (cf. (Isberner et al. 2015)) into their projects. After easing the learning framework by providing a simplified Web interface (Bainczyk et al. 2016, 2017), this percentage went up to 80–90% in recent years. In the meantime, students start to appreciate the learning technology as a powerful support for testing-based quality assurance.

Learning Application and System Design in Capstone projects

TU Dortmund has a mandatory Project Group (PG) for master students similar to capstone projects elsewhere, but training the students through larger-scale collaborative projects: in a PG, 12 students work on a single complex project for a whole year.

In recent years, many PGs used Cinco to develop specialized XMDD languages for a variety of domains. Students are taught a deep understanding of XMDD principles: they *use* an XMDD-based framework (mostly Cinco) and also experience the (guided) *development of an*

own domain-specific XMDD framework for the domain in question.

Recently covered topics span a broad variety of application domains:

[2019] The **Alexa PG** created a modeling environment used to develop “skills” for Amazon’s Alexa Voice Service. Central to this environment is a Cinco-based graphical modeling language for the specification of User/Alexa interactions in a flow graph style. Those “Alexa Skill Workflows” are then fully generated into code and deployed into Amazon’s cloud services.

The PG realized additionally integration with the DIME framework, so that the business logic underlying the skills can be modeled using DIME processes and data models.

[2018] The **ACC++ PG** developed a collection of domain-specific languages for the domain of specifying and testing autonomous driving functionality. The project had two aspects: the definition and implementation of DSLs for the specification of Advanced Driver Assistance Systems (ADAS) based on sensor inputs and actor outputs, which resulted in a specialized Statechart language. It also developed DSLs for test scenario specifications that supported the automatic simulation of the ADAS systems.

[2017] The **GenGa PG** developed an engine for “Generative Game Development” on top of the DIME framework. Focusing on board games and simple animations, the project resulted in various Cinco-based graphical languages for the specification of game boards, tokens, players, and logic.

[2016] The **Bridging the Gap PG** developed a whole family of graphical DSLs for the specification of control software running on an industrial plant. (Wortmann et al. 2016) The variety of DSL developed in the project and their connection and role is illustrated in Fig. 5.

Before Cinco, the jABC framework was used at TU Dortmund as primary technology for XMDD teaching in PGs. Also there it was used to teach XMDD concepts on both the meta level

and the application domain level, but with far less clarity and framework-based correctness checks and automation. The jABC was used in PGs concerning

- KrisenPlan: Planning Games for crisis management in Data and Computing centers (PG592, 2015)
- ProBio: Process-oriented management and analysis of biomedical data (PG586, 2014)
- AgES: Aspect-driven development of secure control systems (PG576, 2013)
- SASSD: Situation-Aware Semantic Service Discovery (PG566, 2012)
- Eclipse4Bio: Use of jABC to extend Eclipse to a domain-specific design and development system for biology-related workflows (PG558, 2011–2012)

In addition to the use of XMDD and Cinco in the undergraduate and graduate level education, several intensive short courses (typically 2 days) at the PhD or graduate school level were held in various countries and locations.

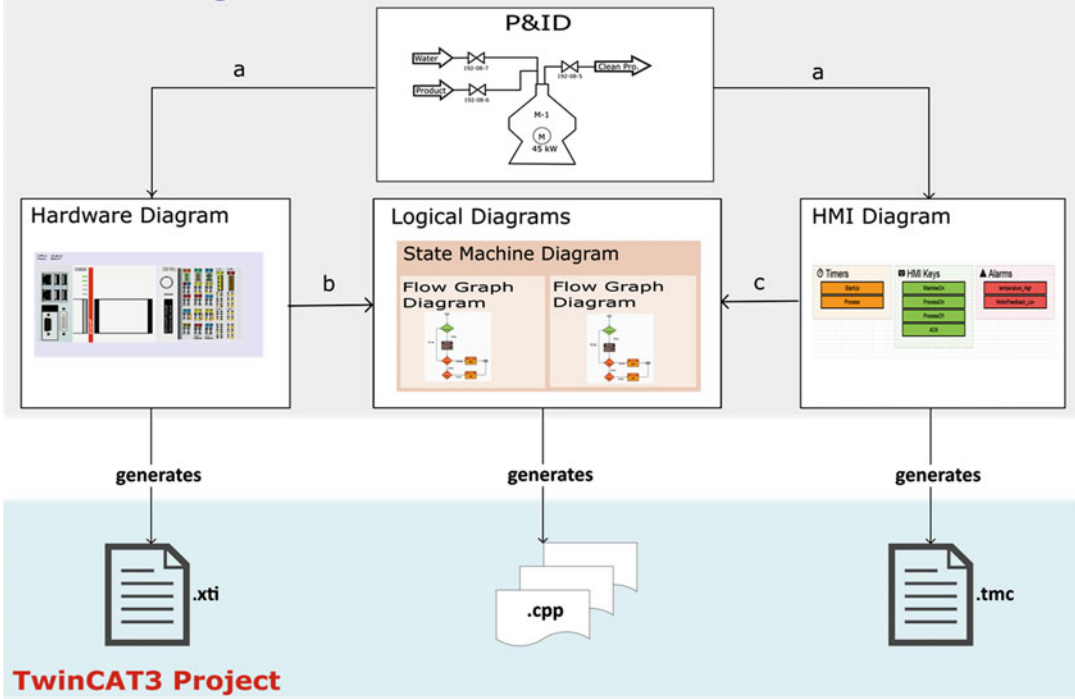
In the International School on Tool-based Rigorous Engineering of Software Systems (STRESS), there were specific trainings on.

- Bootstrapping in the Cinco framework: uses of a graphical metamodeling language developed with Cinco for Cinco (2018)
- Language-Driven Engineering applied on the domain of decision diagrams for email classification (2018)
- Using the “WebStory” modeling language to specify interactive browser games and extending the environment with Cinco metamodeling and code generation (2016)
- Building a PetriNet modeling and simulation environment for simple place/transition nets with Cinco (2014)

Learning the Connection Between Agile Modelling and Design Thinking

In 2017, a week-long course on Agile Design Thinking: Agility through Extreme Model-Driven Engineering took place at the Politecnico di Torino (Italy) as part of the interdisciplinary

Overview Diagram



eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding, Fig. 5 Overview of the four

diagram types (generated with Cinco) in the case study of (Wortmann et al. 2016)

Didattica di Eccellenza in the SCUDO graduate school. The course included theoretical and practical units, and a subsequent individual project with DIME by the students. The course showed how to achieve (a) application-level control, i.e., the continuous involvement of the customer and application expert along the entire systems' life cycle, including software maintenance and evolution, together with (b) continuous and ongoing quality assurance with different means at different levels and phases (requirement validation, simulation, model checking, data flow analysis, testing, and monitoring), and (c) specific support to integrate in an easy and noninvasive fashion new technologies, in a service-oriented way. The key to the approach is to view the whole development process as a creative endeavor that needs to explore, evaluate, optimize, and evolve both the “thing” under design and its context and human/social aspects. In this sense, it is an agile embodiment of the “Design Thinking” paradigm.

In 2018, a shortened course took place in Limerick (2 days).

Learning Software and Systems Verification

Given a model and the rules of the game, like business rules, policies, governance, or compliance requirements, check whether the model respects the rules. If not, provide detailed diagnostic information – typically in terms of a violating run.

In the Foundations of Semantics and Model Checking in a Software Engineering Course (Bordihn et al. 2015) introduced in 2010 at the University of Potsdam in Germany, described how they included a selection of formal methods in a foundational Bachelor-level Software Engineering course. They showed how to introduce the basic elements of modeling and programming language semantics, and discuss how to address the theory and practice of model checking within the scope of the two semesters of the course. In

particular, the first term, SE1(6ECTS) focused on design: the domain level and modeling languages, addressing and contrasting traditional versus agile software development. It introduced model-driven (MDS) approaches, domain-specific languages (DSLs) as fundamental feature of MDS approaches, and meta-modeling as a tool for determining the abstract syntax of a DSL. While the focus was on the concepts and the modeling attitudes underlying these approaches and technologies, some of them were practiced using corresponding analysis and modeling tools.

- **SLGs as Formal Models:** Kripke Structures, Labeled Transition Systems, and Kripke Transition Systems are introduced as suitable abstract model structures. Semantically, SLGs are in fact Kripke Transition Systems (cf. (Müller-Olm et al. 1999)) that combine classical Kripke Structures (cf., e.g., (Clarke et al. 1999, Chapter 2)) with Labeled Transition Systems (cf., e.g., (Kruchten 2004)) into model structures where both states and transitions are labeled. As such, they are directly amenable to formal analysis techniques, in particular to model checking.

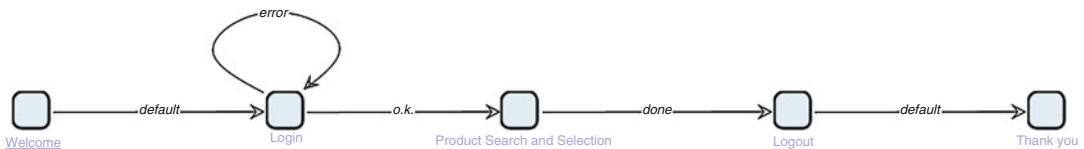
The processes are modeled as SLGs using only Prototype SIBs, like the abstract web shop process shown in Fig. 6. These SIBs are pure modeling means, as they do not have an actual implementation, but as the implementation is not relevant with regard to this kind of abstract model checking, they are sufficient for the purpose. Then system requirements are formulated as temporal properties.

- **Temporal Logic Properties as Constraints:** Starting from the propositional logic already familiar to the students, Hennessy Milner Logic (HML) (Beck and Andres 2004),

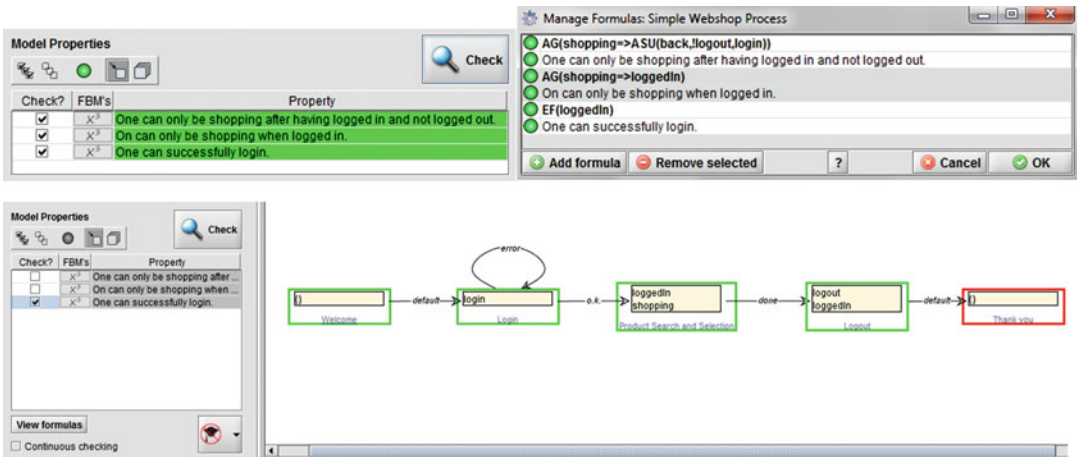
Propositional Linear Time Logic (PLTL, cf. (Margarita and Steffen 2009b)) and Computation Tree Logic (CTL, (UML 2.5.1 specification 2017, Chapter 3)) are introduced as tailored domain-specific languages to formulate behavioral properties. While GEAR is internally a mu-calculus model checker, only CTL would be strictly necessary. HML and PLTL are included primarily for didactic reasons, as they provide good scaffolding for understanding CTL, especially regarding the role of the temporal operators along the paths and the path quantifiers. In the two associated labs, students practice the use of HML, PLTL, and CTL by modeling intuitive properties in terms of these logic languages thereby learning to interpret logical formulas in a comprehensible way.

- **Model Checking:** Finally, the students learn how SLGs can be viewed as Kripke Transition Systems, how to use GEAR to assign atomic propositions to the SIBs of the SLGs, how to enter logical formulas, and how to check and debug systems with GEAR. The use of GEAR is demonstrated by means of some simple examples, where the level of the student's independence is gradually increased.

With the GEAR formula manager, students can edit CTL formulas and document them with natural-language descriptions. The model checking inspector displays all currently available properties, and one can toggle between the formulas (Fig. 7 top right) and their high-level descriptions (Fig. 7 bottom left). In the hands-on sessions, students learn to find out which properties hold for the entire model (i.e., for the start SIB) or individually for each node in the model. The nodes where the formula holds/does not hold are highlighted by



eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding, Fig. 6 The abstract web shop process (standard and Atomic Propositions view)



eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding, Fig. 7 Checking a single property for the whole model

green/red boxes, respectively, as shown in Fig. 7 (right).

The students work in their projects with larger and more complex examples than the illustrative tiny model shown here.

The course was attended by over 250 students. Approximately half of the participants were enrolled in the B.Sc. Computer Science (2010–2014) or B.Sc. Computational Science (2015); the other half of the participants were students in the B.Sc. Business Informatics. There has been no observable difference between these groups regarding the achievements in the exercises, exams and projects. There was, however, a significant difference among the skills developed by these students and those of the precedent years: While the previous generations were more confident in architectural issues and coding skills, these students have a more intuitive confidence with application development and with mastering a number of different technologies. The advantage of this abstract and behavior-driven modelling manifested itself in their approach to the subsequent module on Foundations of Service Engineering, where the black-box character of components is really central. The familiarity with the basic formal methods concepts was also advantageous in the subsequent specialized course on Formal Methods in System Design

(FMSD): taught in an e-learning fashion via teleconference-based lectures shared with the TU Dortmund and complemented by local tutorials and laboratories. It was clear that the Potsdam students had a smoother approach to the more technical material in FMSD due to their previous experience with the basic concepts.

Learning Meta-Modeling and Language Engineering

Every term, an average of 20 Bachelor students in Computer Science – mostly in their final year – are taught in TU Dortmund the XMDD paradigm as well as the fundamental concepts of meta-modeling and language engineering using Cinco. This concerns both textual and graphical modeling languages.

The course itself is split in two parts: some weeks of classroom teaching along with tutorial-style assignments are followed by a practical assignment to be solved autonomously in pairs. The practical assignment includes the development of graphical editors with Cinco in order to realize a configurator for a specific product using well-defined components that are defined in a textual language. Here the focus is on creating and linking a heterogeneous landscape of languages in order to build and maintain a central development artifact in a consistent manner, following the “One-Thing-Approach” (Margaria and

Steffen 2009a). The assurances of syntactic correctness as well as the validation of the model semantics supported by the “consistent by construction” approach in Cinco are vital aspects to achieve this goal.

The course and the development of Cinco mutually enrich and reinforce each other, in particular in terms of simplicity. They observed that both the quantity and quality of the solutions created by the students noticeably increased with Cinco as it became over the year a more intuitive development tool. However, it is remarkable that even students with little or no experience in meta-modeling and language-driven development can produce sophisticated solutions with Cinco after a short training period.

Discussion

XMDD replaces the global and slow roundtrip-based communication between stakeholders often working with completely different means. This contrasts with “traditional” programming-first approaches as well as with model-based but document-centric software engineering approaches like the Rational Unifying Process (RUP). It can be regarded as systemized, low-code, and tool-based enhancement of eXtreme Programming and agile methods (see <https://www.agilealliance.org/agile101/the-agile-manifesto/>) like Scrum (see [scrum.org](https://www.scrum.org)).

Like XP for programming in the small, the XMDD approach revolutionizes process and application development by replacing the typically long intervals between contract-and-requirements time and delivery-and-acceptance time – with all the associated pitfalls – by a continuous, cooperative development process that immediately reveals misconceptions so they can be addressed as soon as they arise.

Why Is it Relevant

Understanding of the application under construction – the user experience – builds naturally along the way. In particular, this new view of cooperation between the customer and the contractor/developer reduces the need for complex and expensive specification documents. These all too

often impose design decisions before the customer can judge their impact, and they often turn out to be obstacles when adjusting the project in the overall context. In contrast, the cooperative development and evolutionary style of XMDD supports the agile adjustment by focusing on the following points:

- **Continuously update the customer:** The impact of each design decision on the application logic becomes apparent via the OTA, which provides customers with a continuously updated user experience.
- **The Focus on the application logic** lets developers repair and modify at the level where the need appears, while following the service-oriented paradigm makes noninvasively exchanging or integrating third-party functionality easy.
- **Constraint analysis:** At any stage, developers can verify the formulated constraints via local checking and data-flow analysis to ensure parameterization and configuration constraints, and can use model checking to ensure global properties concerning protocols, version compatibility, policies, or legal process requirements.
- **Code generation:** Once all required elementary services are implemented, stand-alone code can be generated to fully match the tracer behavior and also manage aspects like role specifications, rights, permissions, security, load balancing, and long-running transactions management.
- **Monitoring:** The runtime environment tracks resource consumption and availability as well as the progress of individual process instances according to their defining models.

These points can be considered the cornerstone for new customer-oriented software development, which aims at raising quality and fit of produced solutions while lowering the total cost of ownership.

The Benefit to Education

From an educational point of view, there are three main benefits, as the XMDD-oriented, tool-

centered teaching approach allows students to experience the impact of

- Design thinking (think the project from the users' perspective)
- Computational thinking (put the user process in the center) and the
- Generative approach to system development (trust the tool chain!)

Today, facing service orientation and an increasing interest in user-defined business processes, lightweight formal methods should be integral part of the standard academic software engineering education. The experience in the foundational Bachelor-level Software Engineering course with four embedded formal methods components at the University of Potsdam in the period 2010–2015 and the first year bootstrap module in Limerick (2016–2019) have confirmed the usefulness of the computational thinking approach and the choice of using XMDD in a modern, low-code, generative system development framework.

Choosing only so-called lightweight formal methods, i.e., methods with fully automatic algorithms and tools (like type checkers and model checkers), and not theorem provers or proof techniques for program correctness like Hoare-style program verification (both presented at length in other courses), was done on purpose, in order to provide scalable approaches that have a low threshold to adoption, ease of reasonably confident use in the small, and a high ease of embedding in a full-fledged model-driven IDE.

While high-end Formal Methods continue to require a deep knowledge of the mathematical concepts and formalisms, IDE-embedded Formal Methods should be made available systematically to the next generation of Software Engineers as part of their basic profession-oriented education. Like basic English has successfully become within a generation a standard in schools, establishing itself culturally as the “lingua franca” of international communication, the ability to take a domain-specific perspective, to think in terms of domain-specific properties, to formulate them in

such a way that both a user and a tool are able to work with them, and the ability to conduct verifications on early models of a system are the key to a better understanding between IT professionals, in particular Software Engineers.

Another advantage is the ingrained sense of accountability and ownership that comes with the ability and habit of verifying early and verifying often, by means of tools that take an objective perspective (other than user inspections) and provide a third party repeatable outcome. With all the limitations and drawbacks known of the FM tools and approaches of today, such a step towards accountability for decisions and outcomes early in the design constitutes a central shift towards maturity of the professional figure, competence beyond the production of code, and ultimately towards establishing a new concept of ethics and responsibility in the Software Engineering profession.

Conclusions

When the XMDD-paradigm entered software engineering classes almost 20 years ago, this low-code and formal approach was not always appreciated. In fact, even today there is some resistance from the classical programming-oriented educational establishment. Some of the arguments are that the established Computer Science and Software Engineering curricula, e.g., by the ACM, do not talk at all about low-code approaches, include models in the traditional descriptive sense and not as executable artifacts, and list formal methods as advanced topics, to be retrofitted on the students as electives once the foundations have been laid through code-first approaches. One can counter that those curricula, as of today, do not list Artificial Intelligence or Machine Learning either: this is a consequence of the well-known fact that, like standards, such curricula trail, instead of leading, both the knowledge development and the adoption in practice.

Today's general movement towards the application expert and the increasing prominence of design thinking indicates, however, that XMDD is on the right track. In particular, with the

growing maturity of the XMDD tools, students start to appreciate the potential and the power not only in class but also in “real life.” This is reflected in the growing number of students explicitly asking for corresponding thesis topics. If Gartner is right in forecasting the massive adoption of low-code development environments, the next generation of ACM curricula will likely prominently include them.

Cross-References

- [Agile Methodology in Education of IT Students, Application of](#)
- [Computational Thinking](#)
- [Modeling of Games and Game Strategies](#)
- [Software Development Processes Designed for First Year Computing Undergraduates](#)

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Facebook Use in Malaysian Higher Education Classroom

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Synonyms

Social media; Social networking site; Technology-enhanced learning; University classroom education

Introduction

Recent studies have shown that social media technology plays a role in facilitating teaching and learning in higher education (Bryant et al. 2014). Social media is recognized as a popular social communication channel, and in recent years, there is an increased interest of educators for using social media in higher education as a technology-enhanced learning environment. In addition, the rapid advancement of technology, such as social media, offers new opportunities to university students for more access to information and interaction, increasing their chances of achieving better academic performance and

affecting education in terms of pedagogical purposes (Laskin and Avena 2015).

The use of social media by university lecturers and students has been an interesting research area for educationists and social scientists. The Social Media Survey 2013 by Pearson shows the increase use of social media for teaching by educators and faculty professionals because they see the potential in applying and integrating social media technology to their teaching practices (Seaman and Tinti-Kane 2013). This creates a growing phenomenon for the educational use of social media to create, engage, and share existing or newly produced information between lecturers and students and among students (Lee et al. 2015). Some researchers perceive social media tool as an effective educational platform because it allows educators to make the classes more interactive; on the other hand, there are researchers who state that the use of social media has hindered the achievement of student learning outcomes (Lee et al. 2015).

Although social media is considered a double-edged sword, research on social media use, such as Facebook, in higher education has grown rapidly with an increasing number of educators and researchers who believe that Facebook provides an environment that supports university students' active learning. Facebook is the most popular social networking site which has received considerable attention from a large number of research areas particularly in social sciences (Manca and Ranieri 2016). Facebook was established in

February 2004 by Mark Zuckerberg for Harvard University students and later opened for public membership in 2006 (Grossman 2010). To date, Facebook has 2 billion monthly active users (Techcrunch.com 2017). Among them, university and college students hold the highest percentage of active Facebook users, extensively sharing information on Facebook (Abdulahi et al. 2014), and used it as a tool of relaxation and entertainment in between their studies during the university and college days (Kashif 2013).

For example, Facebook groups are used by students for creating discussion forum and receiving updates from their instructors on their newsfeed and by instructors for sharing and communicating with their students about course information, examinations, assignments, and announcements through the group posts (Al-Bahrani and Patel 2015). Despite the excitements surrounding the potential of Facebook in higher education, researchers have waved the yellow caution flag on the over-privileging the site for actual pedagogical purposes. Some researchers who are not positive about Facebook use reported that the negative feelings were a recognition that the use of Facebook for English language learning simply had not helped improve students' English language (Tess 2013).

Regardless of the pervasive use of Facebook in higher education, there is a mixed result on its perceived impact for teaching and learning in classroom education. With that in mind, this study, part of a work-in-progress research project, provides insight about the adoption of Facebook by lecturers and students in a formal classroom education in Malaysia, as well as how the lecturers and students perceive Facebook could enhance learning experiences, supporting and improving teaching practices. The preliminary findings of this study contribute to the understanding on how and why lecturers and students leverage Facebook as a teaching and learning tool in Malaysian higher education classroom. The remaining sections of this paper is organized as follows: a review of literature on the uses and impacts of Facebook in higher education, a methodology section which describes the procedure of data collection and analysis, a findings and

discussion section which present the answers for the two research questions, and lastly a conclusion section which summarizes the findings of this study in achieving the research objectives.

Literature Review

Research on Facebook use in Malaysian educational contexts has been growing at a rapid rate. The criteria have taken into consideration the inclusion of the studies in this literature review including the scope of study and the academic profile of the journals. Firstly, the selection of literature is based on the uses and impacts of Facebook in higher education. The keywords used for finding these studies are "Facebook and higher education," "Facebook and Malaysian higher education," "Facebook use in higher education," and "uses and impacts of Facebook in higher education." Next, the literature is based on empirical research published in scientific journals, postgraduate theses, dissertations, and other contributions such as conference proceedings and research reports. Lastly the literature is searched through EBSCOhost, Google Scholar, and the Google search engine. The following paragraphs discuss the two themes of the study: uses of Facebook in higher education and impacts of Facebook use in higher education.

Social media, such as Facebook, is an established part of the communication networks and has great potential for networked learning, both within and outside the boundaries of the physical classroom (Freeman 2014). Besides, Facebook has gained a unique position as a learning technology for educational purposes because students created a Facebook group for managing educational content and it provides a conducive environment for student interaction (Ahern et al. 2016). Literature reveals that it is proven to be feasible for learning English in Facebook due to its features which "are able to engage students in meaningful language-based activities" (Kabilan et al. 2010, p. 185). In addition, Manca and Ranieri (2016) in their analysis show that Facebook is still mostly considered as an alternative to traditional learning

management systems (LMS), though they concluded that the pedagogical affordances of Facebook are still partially implemented.

The use of Facebook by lecturers and students as reported in the literature is due to the “dynamic development of the Web 2.0 and new trends in the social media field” (Tanta et al. 2014, p. 86), and the usage could be explained through the Uses and Gratifications Theory as why and how individuals actively select specific media outlets to satisfy specific needs (Katz et al. 1974, as cited in Ifinedo 2016). Scholarly research has drawn upon the Uses and Gratifications Theory to examine the consumption behavior and motivations of individuals using Facebook – information exchange, conformity, freedom of expression, social maintenance and recreation, making new connections, socializing, entertainment, self-status seeking and information, passing time, showing affection, following fashion, sharing problems, demonstrating sociability, and improving social knowledge (Phua et al. 2017).

In the Malaysia context, most researchers agree that the implementation of Facebook in Malaysian higher education produces positive impacts, especially in language and writing classes (Ng and Maniam 2015) and improving students’ academic performance (Helou and Ab. Rahim 2011). Ng and Maniam (2015) investigated the perceptions and attitudes of 15 students from a college in Peninsular Malaysia toward the use of Facebook group discussions. The results show a positive attitude of the college students on the use of Facebook group discussions, and there is a “significant effect of Facebook group discussion on students’ writing performances” (Ng and Maniam 2015, p. 36). In another research, Helou and Ab. Rahim (2011) measured students’ perceptions on the use of social networking sites and its impact on students’ academic performance. Based on a survey with 30 undergraduate and postgraduate students of a public university in Southern Peninsular Malaysia, most respondents felt that social networking sites have more positive impact on their academic performance due to its use “for various academic activities such as communicating with the faculty and university authority, communicating with lecturers and

supervisors, making academic discussions with classmates and chatting with friends in respect to topics of educational interest. While the negative impacts of the social networking sites towards their academic performance are considerably low” (Helou and Ab. Rahim 2011, p. 7).

Lastly, Facebook also brings benefits in students’ learning experience as a platform for online discussion (Abdul Rahman and Mohd Amin 2014), a supplementary tool for team-based learning (Rasiah 2014) and an alternative tool for student engagement (Sim et al. 2014; Haque et al. 2015). Abdul Rahman and Mohd Amin (2014) examined the effectiveness of Facebook as a teaching aid for a subject at a private university in Malaysia. Through a descriptive questionnaire survey with 300 students, the results demonstrate that “the relationship between the students and their lecturers can be improved and this indirectly will influence the students’ performance in the subject” (Abdul Rahman and Mohd Amin 2014, p. 333). Rasiah (2014) on the other hand conducted a content analysis on 122 students’ reflection journals on their learning experiences of undertaking the group and individual projects as well as their perceptions on the effectiveness of Facebook use in enhancing their learning experience and competences. The author concludes that students perceived the use of Facebook as beneficial for instructional purposes and there is clear evidence on the effective use of Facebook in enhancing team-based learning outside the classroom, complementing face-to-face lessons (Rasiah 2014).

In terms of student engagement, Sim et al. (2014) collected the data through a student survey, postings in the Facebook group, and a short essay from the lecturers concerning their experience of using Facebook as a tool to engage students in the class. Results show that the feedbacks received from both lecturers and students were positive because Facebook features encouraged student participation and engagement in Facebook groups, and the authors conclude that Facebook is the suitable tool for student engagement (Sim et al. 2014). Haque et al. (2015) distributed a structured survey to 500 students of various private and public higher learning institutions in Malaysia.

Data drawn from 398 usable questionnaires shows that students perceived Facebook as an alternative learning tool in the Malaysian higher learning institutions and “the characteristics of social networking sites such as ease of use, intricacy, adaptability and observability might affect the attitudes towards adoption of Facebook as a learning tool” (Haque et al. 2015, p. 1631).

Prior research shows that Facebook is useful for learning environments (Kabilan et al. 2010) and Malaysian students have been using it for informal learning purposes (Hamat et al. 2012); this in return has resulted a positive impact on their academic performances (Al-Rahmi and Othman 2013). Facebook is perceived as an innovative and effective tool in a student-centered learning environment because it “created a more positive and less-threatening learning environment which enhanced the students’ engagement and learning experience while creating a stronger rapport between each other and with the lecturer” (Rasiah 2014, p. 377). In addition, lecturers of Malaysian universities also begin to use Facebook to complement their current teaching and learning practices (Hamid et al. 2011).

Although positive results of Facebook use in higher education were shown in prior literature, differences were found “between the well-proven potential of technology-enabled learning and the less consistent realities of technology use within university teaching and learning” (Henderson et al. 2015, p. 1). Lim et al. (2014) further claimed that successful adoption of Facebook in Malaysian higher education institutions depends on many factors because students, academics, and the institutions themselves have views and practices that do not necessarily align. The use of social media technologies, especially Facebook in higher education, is not an easy and straightforward process. Therefore, more research efforts are needed to integrate social technologies in higher education and for effective use in formal learning contexts (Deng and Tavares 2015).

A mixed result in the empirical literature shows inconclusive evidence on the uses and impacts of Facebook in higher education classroom. Drawing on the literature review of Facebook use in the Malaysia context, two research

questions guiding this study are: (RQ1) How is Facebook utilized in Malaysian higher education classroom? (RQ2) How is Facebook perceived as an effective teaching and learning tool in classroom education?

Methodology

This study took place at two private universities in the Klang Valley, Malaysia. Both universities are known to have a focus on innovative uses of technology in teaching and learning. A qualitative research method, semi-structured interview was adopted. Semi-structured interviews enable researchers to understand how social media technologies such as Facebook is integrated by educators into their teaching because the participants were asked about their expectations and experiences of using the technology as well as the pedagogical choices made when integrating the technology into teaching (Freeman 2014). The most important advantages of using interview are the wealth of detail and focused responses that it provides regardless of the difficulty in generalizing the data and the possibility of not getting the whole truth (Wimmer and Dominick 2014).

A semi-structured interview with three participants – two lecturers and a student – who used Facebook for teaching and learning in classroom education was conducted at their university campus on 11 and 14 January 2017 with an average duration of 46.8 min (ranging from 40.1 min to 53.1 min). The participants have voluntarily participated in the interviews, and they were able to answer the ten questions asked during the interview. The questions focused on their usage of technologies such as Facebook in higher education classroom, the advantages and disadvantages of Facebook use, and the perception on the effectiveness of using Facebook for teaching and learning in classroom education. The participants volunteered to share their experiences and perspectives of using Facebook as a teaching and learning tool in a Malaysian university classroom. The interviews were audio-recorded and further transcribed into 76 single-spaced pages of

transcriptions in English. The data from the interviews were content-analyzed using thematic analysis.

Findings and Discussion

In terms of Facebook usage in the Malaysian higher education classroom, findings indicate that Facebook is a popular networking site used by the lecturers and students as a teaching and learning and communication platform for formal classroom education. The lecturers of two private universities in Malaysia are using Facebook as a platform for students to ask questions about the subject, making announcements and online discussion. An active Facebook user such as a university student has used Facebook group for discussion among peers about lessons and assignment topics. The finding on how Facebook is used in the Malaysian higher education is consistent with the studies of Kabilan et al. (2010), Rasiah (2014), and Haque et al. (2015). Facebook is utilized as an online environment to facilitate learning and communication in the classroom and as “an avenue for a ‘formal’ academic discourse, whereby explicit assignments and tasks related to learning... could be integrated” (Kabilan et al. 2010, p. 185). It is also used for communication and announcement purposes due to the fact that Facebook is a medium suitable for making announcements (Haque et al. 2015) and useful for managing large classes (Rasiah 2014).

When the lecturer and student participants are asked why they choose to use Facebook for classroom education, the lecturers highlighted that opening a Facebook account is free of charge; it is easier and faster to use Facebook to communicate to students, especially to large group of students; it allows lecturers to feel connected to their students; there is more and better interaction with students; questions about the subject by students were not posted directly to the lecturer but to the class itself which encourages social learning; no constraint of time on Facebook as a way of consultation between educators and students; and students are always on Facebook with their friends; therefore, immediate response can

be garnered. These responses reveal the increased use of social media tools such as Facebook for teaching in classrooms by educators and faculty professionals because they see the potential of integrating social media technology to their teaching practices (Seaman and Tinti-Kane 2013).

The student on the other hand claimed that Facebook is becoming common as university students are often on Facebook and they have easy access to Facebook. Besides, students are more likely to read information and material posted on Facebook compared to the university LMS. The student also asserts that it is easier to share knowledge with others on Facebook, whereby all can learn. It is evidenced that students as active users extensively share information on Facebook (Abdulahi et al. 2014) and use Facebook to create, engage, and share existing or newly produced information between lecturers and students and among students (Lee et al. 2015) as well as use it as a tool of relaxation and entertainment in between their study during the university and college days (Kashif 2013).

The findings further support prior literature that Facebook offers benefits in the aspects of student learning experiences (Abdul Rahman and Mohd Amin 2014) and student engagement (Sim et al. 2014; Haque et al. 2015), complementing the current teaching and learning practices (Hamid et al. 2011) and enhancing academic performances (Helou and Ab. Rahim 2011; Al-Rahmi and Othman 2013). The use of Facebook could be explained through the Uses and Gratifications Theory because individuals actively select specific media outlets to satisfy specific needs (Katz et al. 1974, as cited in Ifinedo 2016). Lecturers and student of this study have selected to use Facebook for educational purposes could be motivated to fulfill their needs for information exchange, conformity, socializing, entertainment, passing time, and improving social knowledge (Phua et al. 2017).

In assessing the perspectives of the lecturers and students on the impacts of Facebook for teaching and learning in classroom education as addressed in research question 2, all participants express an optimistic view. For example, one of the lecturers looks at Facebook as a positive

teaching and learning tool because Facebook enables instant feedback. He argues on how students interact in Facebook is a sign of how well the cohort as a whole is going to perform in the final examination; if those cohorts are active, result is excellent. Another lecturer has used Facebook for online discussion, and she discloses that students are more vocal when they are on Facebook group, even students, who are very quiet, dare to speak out when compared to having a discussion in a physical classroom. These perspectives of the lecturers support the studies of Helou and Ab. Rahim (2011) and Ng and Maniam (2015), in which social networking sites have more positive impact on students' academic performance (Helou and Ab. Rahim 2011), in which the use of Facebook group discussions had significant effect on their performances (Ng and Maniam 2015). Therefore, Facebook has gained a unique position as a learning technology for educational purposes because Facebook group is created for managing educational content and it provides a conducive environment for student interaction (Ahern et al. 2016).

Nevertheless, the participants also acknowledge some setbacks of using Facebook for classroom education. The negative parts of it are as follows: the small fractions of contributors during online discussion; Facebook is a public domain causing the possibility of having outsiders or general publics who are not registered student to be in the group; distractions on teaching and learning practices; too reliant on a single technology; risk of plagiarism and privacy; and the overlapping between work and school with personal matters on Facebook. For example, the student agrees that distraction is one disadvantage of using Facebook for classroom education; however, she commented that distraction arises regardless of using Facebook or any other platforms. Another disadvantage of Facebook use in higher education reported in prior research was the privacy issue (Smith 2016). Despite privacy being the top of the list of concerns (Seaman and Tinti-Kane 2013), when the student was asked about privacy as a limitation of using Facebook,

she claims that it is not a concern for her because she is able to manage her social media account and she is conscious about what to click, what to put on, and how it will reflect on herself. It is noteworthy that the expression on both positive and negative impacts of Facebook use in Malaysian classroom education validates Smith's (2016) conclusion that social media is a double-edged sword that potentially helps and hinders university teaching and learning.

Lastly, the participants provide their views on the uses and impacts of using Facebook for teaching and learning in Malaysian university classroom. The first lecturer explains that when students are using Facebook, they can remain anonymous, but not faceless. He added that students feel safer this way to ask and respond to a question on Facebook, which becomes a good way for lecturers to assess student learning. The other lecturer agrees that social learning can be encouraged through Facebook discussion because students do not have to wait for the lecturer to respond but among themselves they are learning together. In addition, she implies that she will continue using Facebook to allow students to learn what is supposed to be posted and not. Nevertheless, both lecturers warn that Facebook is not a replacement for missing classes because it is just a supplementary tool, not the end-all tool. According to Haque et al. (2015), Malaysian students perceived Facebook as an alternative learning tool in the Malaysian higher learning institutions.

Additionally, the lecturers reveal that students are reluctant to use their university LMS for learning and communication purposes due to students' comfortability on Facebook and the Facebook interface is more interesting and exciting than their university emails or LMS. Importantly, both lecturers and students acknowledge the positive impact of Facebook on students' academic performances especially the usefulness of Facebook group for assignments discussion. The student discloses that Facebook group discussion is effective and helps in student learning because Facebook brings the learning experience outside from the classroom. A similar pattern is

evident in existing studies which indicated that Facebook brings benefits in students' learning experience as a platform for online discussion (Abdul Rahman and Mohd Amin 2014), in particular Facebook groups are used by students for creating discussion for assignments through the group posts (Al-Bahrani and Patel 2015).

Despite the benefits of using Facebook in higher education and the ubiquitous usage by students, one study claimed that teachers are hesitant of promoting the use of Facebook in the classroom (Raman et al. 2014), yet both lecturers of this study disagree. The lecturer participants are positive in using Facebook group because they perceive Facebook to be a safe environment for students to learn and they are able to cast a wider net to reach a bigger audience. Rasiah (2014) in her study concluded that Facebook is perceived as an innovative and effective tool in a student-centered learning environment because it enhanced students' engagement and learning experience (Rasiah 2014).

Conclusion

In this study on the use of Facebook in Malaysian higher education classroom, the goal was to look at the use of a social media technology – Facebook – for teaching and learning, and to explore the perception of lecturer and student in considering Facebook for effective classroom education. The findings suggest that the pervasive use of Facebook especially by university students has led to classroom use, and to feel connected to students and instant interactivity are the precursors to technology adoption by the lecturers. Besides, the findings of this study demonstrate similar outcomes with Freeman's (2014) study that the impetus for faculty members to use Facebook as a tool in their classrooms is distinctly pedagogical and not technological. The findings for both research questions concur with the research of Hamid et al. (2011); Hamat et al. (2012); and Ahern et al. (2016) that Facebook has a unique and powerful position to transform teaching strategies as well as the potential to

enhance and improve student learning (Ezell 2016). Thus, this study provides an empirical evidence that complements prior literature on the uses and impacts of Facebook in Malaysian higher education. The participants further recognize and value the benefits of using Facebook for teaching and learning in higher education classroom; hence, this study supports the earlier claim of the pedagogical rationale for using social media technology in classroom education. This study concludes that using Facebook is an opportunity for effective teaching and learning practices in Malaysian higher education classroom.

Cross-References

- Classroom Use, Blended Learning
- Social Media and Networks as Digital Instruction and Learning Platforms
- Social Media for Tertiary Education
- Social Networking in Higher Education
- Technology Enhanced Learning

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- [Android-Based Mobile Apps for Hands-On Education](#)

First Nation

- [Safe Frames, Essential Determinant for Educational Technology Implementation in an Indigenous Context](#)

First Programming Language in Introductory Programming Courses, Role of

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Synonyms

[Introductory programming language](#); [Novice programming language](#)

Introduction

The *Introduction to Programming* is an important field and at least one course with this or a similar title exists in all Computer Science (CS) and Information and Communications Technology (ICT) bachelor studies (Moritz and Blank 2005). A programming language selected for such a course should provide a notion in which to express algorithms, techniques, and data structures and focus on teaching programming and acquiring programming skills (Goosen et al. 2007). Computer science is a theoretical, as well as a practical discipline, and usually it deals with the science of computation, art, and craft. So, it is extremely important to learn an appropriate programming language (PL) in the first course in computer science.

Different factors and concerns (Ali and Smith 2014) influence the choice of the first programming language (FPL) for CS and ICT studies, and it is extremely important to differentiate key features of a language in the educational context. This is particularly valid today when we face dynamic evolution in the contexts and impact of ICT on individuals with the advent of Internet of Things, smart technology in virtually any corner of everyday life, as well as virtualization and cloud technology in the backend of ICT systems. The choice of the FPL in CS or ICT undergraduate studies can also be affected by previous experience of the learners which may vary significantly (Strong et al. 2017). The factors that influence the choice of the FPL are driven by didactical and pedagogical issues, business and technology development, as well as regional requirements, trends, and issues. Nowadays, for ICT teachers, it may seem that the choice of the FPL is a long-resolved matter. Even non-ICT teachers believe that it is obvious which language to use for teaching programming at bachelor studies. Therefore still there are a lot of papers that seriously consider this problem. Still the majority of teachers of programming topics are in dilemmas which programming paradigm and language to choose as first (Aleksić and Ivanović 2016), as this decision is considered to have a strong impact on later courses and finally on the development of a programmer.

During the history of developing numerous programming languages, some important programming paradigms have been recognized: imperative, object-oriented, functional, and logic. At the majority of universities in ICT curricula, the first two paradigms are still predominant though the functional paradigm gains on importance as the functional features are available and widely used in many of today's mainstream languages. Some teachers like to teach the most popular PLs but there are numerous possible measures of language popularity like: Most widely used? Most jobs offered for the knowledge of the particular language? Most lines of code existing in the language? And so on. Another problem connected to the popularity of programming language appears: Is the popularity of a language, a guarantee of its suitability for teaching programming concepts? Based on the above mentioned, it is clear that it is not possible to propose and select the best language for all situations.

In the last two decades with the appearance and intensification of use of some particular languages again a lot of debates appeared focusing on the choice of the FPL. Should teachers teach C, Java, C#, Python, Perl, Scala, JavaScript, or something else? Some authors plead that if the choice of a language is a key point then teachers are on the road to failure already. More and more institutions adopted Java in their introductory programming courses the last years but more recently Python is getting more and more popular. Nevertheless there is no universal satisfaction with a particular decision. As the choice of the FPL for ICT education is not an easy task, teachers have to be aware of this and continuously reevaluate language choice for their introductory courses.

In this entry, issues that are related to the role and choice of the FPL in introductory programming courses are presented. These issues are presented in the context of the relevant literature and the experience of the authors as well that have been teaching introductory programming courses for several years in three different Higher Education European Institutions: the University of Macedonia in Thessaloniki, Greece; the Masaryk University in Brno, Czech Republic; and the University of Novi Sad in Novi Sad,

Serbia. The rest of the entry is organized as follows. In section [“Goals and Syllabus of a Typical Introductory Programming Course,”](#) the goals and the syllabus of a typical introductory programming course are presented along with a short description of the introductory programming courses offered at the aforementioned institutions. In section [“Review of Research on the Effects of the First Programming Language,”](#) a review of the research carried out the last decades on the effects of various programming languages utilized as FPL in Higher Education Institutions around the world is presented. This is followed by a brief presentation of teachers' perspective on the choice of the FPL in section [“Teachers' Perspective on the Choice of the First Programming Language.”](#) More specifically, the main criteria that affect the choice of the FPL as recorded in the literature are briefly presented along with the factors that affected the choice of the FPL throughout the years in the authors' institutions. In section [“Students' Perspective on the First Programming Language,”](#) the perceptions of students from the aforementioned Higher Education Institutions regarding the FPL are presented based on a specially designed survey. The entry concludes with some remarks regarding the role of the FPL in introductory courses and some remarks regarding its overestimated impact on the success or failure of students in introductory programming courses. It is clear that the choice of the FPL is important but other important factors, such as the exploitation of Education and Information Technologies and generally the teaching approach utilized, should be taken seriously into account.

Goals and Syllabus of a Typical Introductory Programming Course

Most instructors agree that the main learning goals and outcomes of the FPL course are to support students in:

- Developing an algorithmic way of thinking and reasoning
- Acquiring problem solving skills

- Learning and applying the main programming concepts that exist in nearly every programming language, such as variables, control structures, strings, functions, and arrays
- Learning to design and code simple algorithms
- Learning to use contemporary programming environments for implementing and debugging programs
- Acquiring good style programming habits

Emphasis is not given on the details of the specific FPL, but on concepts and skills considered necessary for further learning other programming languages, either in the context of some other programming courses or studying them alone. Moreover, the aforementioned skills are the first skills that have to be developed in terms of employability and research in the ICT field.

As already mentioned, various programming paradigms or techniques exist nowadays, but the two most utilized in introductory programming courses are the imperative and object-oriented programming paradigms. No matter what the selected programming paradigm is, an introductory programming course usually deals with fundamental programming concepts, such as: data-types, variables, sequential structures, selection structures, repetition structures or loops, functions/methods, strings, arrays, manipulation of text files, and so on.

Our institutions have adopted the “imperative first” approach in the past based on C-like and Pascal-like languages for teaching the FPL. Recently new languages have been adopted which will be reported in the rest of the entry.

The University of Macedonia, formerly Department of Technology Management, which has merged with the Department of Applied Informatics, uses the imperative programming paradigm and the C language for the introductory programming course (since 2004) taking into account various didactical and pedagogical issues recorded in the literature (Xinogalos 2016). Specifically, students’ difficulties with the various programming structures as recorded in the literature and the course are taken into account for preparing the educational material utilized in it, a

pseudo-language in students’ native language is used for implementing the algorithm solving a problem prior its implementation in the programming language, and various forms of ICT are utilized for supporting the teaching and learning of programming. The Department of Applied Informatics uses C as the FPL for several years now, while its predecessor was Pascal. The Computer Programming course taught at the Department of Technology Management covered the following fundamental imperative programming concepts: primitive data types, variables, control structures, functions, arrays, strings, pointers, and text files. Currently, the Procedural Programming course taught at the Department of Applied Informatics covers moreover structures, arrays, and files of structures. This introductory programming course is followed by an object-oriented programming course based on Java.

Masaryk University, Faculty of Informatics, is a research and higher educational institution established in 1994 as the first educational institution in CZ primarily focused at computer science and IT. Since its foundation, it used Pascal as the first imperative programming language together with Haskell as the first functional paradigm language. Since 2011, the imperative programming language has been changed from Pascal to C with an alternative Python-based. Starting from 2016, Python entirely replaced the C-based course as the introductory one. The introductory programming course based either on C or Python have in principle the same didactical goals but slightly different techniques to attain them. The C-based introductory course followed a more traditional approach derived from the older Pascal-based introduction to programming course. The main aim of the course Introduction to Programming using C was to introduce students to basic principles of computer problem-solving. At the end of this course, students should be able to: design an algorithm to solve a given problem; code an algorithm in the C programming language; and debug a created program. The topics included basics of I/O functions, expressions, variables, basic statements and control structures, decomposition into functions, data types, and basic algorithms, such as numerical

and text processing algorithms together with some theory of algorithm analysis (correctness, efficiency). After completion of the Introduction to Programming through Python, students are expected to understand and apply basic constructs of programming languages, such as conditions, loops, functions, and basic data types, and will master several basic algorithms and techniques (sorting, searching, recursion, and some fundamental use of the turtle graphics). In general, the C-based course followed rather a “bottom-up” approach building the solution from basic elements upwards while the Python one is more “top-down,” progressing from motivation and problem to the coded solution. Recently (from 2018 onwards), Masaryk University study programs will face another change leading to coverage of (abstract) object-oriented concepts in a separate course to be followed with Java, C#, or C++ mainstream object-oriented language courses.

The University of Novi Sad, Faculty of Sciences used Modula-2 as a typical language designed for teaching programming purposes until 2015. The introductory programming course for computer science studies based on Modula-2 covered the basic concepts of the imperative programming style (primitive data types, statements and control structures, procedures, abstract data types, and recursion). Teachers’ opinion, based on experience spanning multiple decades, is that good educational programming languages (like those designed by Niklaus Wirth) are the most suitable to explain the aforementioned programming concepts to first year students. Modula-2 satisfied most of the desirable educational premises: most of students have pre-knowledge of Pascal so Modula-2 was convenient for them; it offers clean and well-structured features; it is also good for teaching other classical techniques and algorithms. However, in the last years, there was a constant pressure from different sources (like local companies, competition with other faculties with similar study programs, students, their parents, or other colleagues) to change the language used in the introductory course. So in 2016, a decision to teach basic programming concepts relying on Java was made, using an imperative-

first approach and just shortly mentioning objects at the end of the course.

Review of Research on the Effects of the First Programming Language

The choice of the first programming language has been a controversial issue for several decades. Nearly everyone agrees that the FPL is important and affects students’ subsequent education on programming. The importance of the FPL has resulted in extended research regarding the effectiveness of various programming languages and paradigms when used for an introduction to programming (Farooq et al. 2014).

Several studies focus on presenting the results of making a transition from one programming language to another in terms of a more suitable FPL. Next, relevant studies are presented in ascending chronological order with the aim of studying how the landscape on FPL has changed as years passed.

Radensky et al. (1988) report on their positive experience of using, at the time popular programming language Ada, as a FPL. The authors consider Ada to be more appropriate than Pascal and Modula-2 as an FPL and state that students are able to learn Ada easily and quickly. Moreover, students appreciate the advanced features of Ada and write more sophisticated programs. However, these are all based on subjective evidence and later Ada did not appear as widely used language.

Skublics and White (1991) report on their experience of moving from Pascal to Smalltalk. The main reasons for this decision were the simpler syntax of Smalltalk and the fact that it supports more the notions of data and procedural abstraction, encapsulation, and modular programming, as well as the fact that it supports the teaching of concepts prior to their implementation. Students’ grades in the revised course were compared with those of previous years when the course was based on Pascal and no significant difference was recorded. A questionnaire for recording students’ opinion for the course was also used; however, the small number of respondents (14) limits its importance. Students with

prior knowledge of programming stated that they had difficulty in their transition to the object-oriented paradigm. Another problem reported was the extended size of the class library.

Hitz and Hudec (1995) report on their unexpected positive experience on moving from an educational language to a conventional language used in industry. Specifically, the authors based exclusively on didactical considerations used – starting back in 1974 – Fortran, PL/1, Pascal, and Modula-2. Although they considered both Pascal and Modula-2 successful for the purposes of the course, they decided in 1992 to move to C++ in order to satisfy students' willingness to learn a language they would afterwards use in their studies and the market. Object-orientation and inheritance were not taught. No significant difference in students' performance was recorded, while students' feedback was positive. However, no formal instrument was used for investigating students' feedback.

As shown from the last two studies, at some point the research on FPL started to focus in the programming paradigm supported by the FPL. Brilliant and Wiseman (1996) used a survey regarding “the first programming paradigm and language dilemma” that was sent to Computer Science Departments at 145 Universities and received 45 replies. This survey investigated: the procedural paradigm and the languages Pascal, Modula-2, Ada, and C; the object-oriented paradigm and C++; and the functional paradigm and Scheme. Although, Ada seemed a good choice at that time, there did not seem to be a paradigm that offered significant advantages for the first programming course, while students seemed able to move to another paradigm with reasonable ease. However, other studies conclude that students face more difficulties during their transition from procedural programming to object-oriented programming and not vice versa (Decker and Hirshfield 1994; Hadjerrouit 1998a; Tempte 1991; Wick 1995).

As expected, this controversy between paradigms and languages was intensified with the advent of Java. Several papers were published reporting the advantages and disadvantages of Java as a FPL, as well as experience on using it in introductory programming courses. Hadjerrouit (1998b) reports on the experience of moving from

Simula and C++ to Java as a FPL in order to take advantage of object-orientation, concurrent programming, and its combination with the World Wide Web. It turned out that Java is not as easy as expected as a FPL, but it is also clear that it is necessary to incorporate it in the CSE curriculum. Several years later, Jabłonowski (2007) also reported on the great advantages of Java and at the same time its inadequacy as a FPL in comparison to Pascal or Smalltalk for instance. In a contemporary study, Farag et al. (2013) compared the effectiveness of an online introductory course based on C++ (control group) and Java (experimental group), respectively. No statistically significant differences were recorded for the two groups neither in terms of students' achievements nor in terms of satisfaction. Duke et al. (2000) stress out that object-orientation and Java are important for attracting students at universities. However, adopting Java as a FPL is just the first step that offers great opportunities for changing the way of teaching: adopting a problem-based approach; allowing students to work independently on their own pace; applying an inverse curriculum adopting object-orientation from the very beginning.

On the other hand, Ivanović et al. (2015) concluded that the choice of the FPL does not matter if students' performance at the course is used as the only criterion of suitability of the language. The authors presented their recent experience in changing the first programming language from Modula-2 to Java. The main idea was to try to discover if there are any significant differences in students' success between the most recent generation taught in Java, and several previous generations taught in Modula-2. Since there were not many other significant factors distinguishing the generations, they concluded that statistical analysis of collected scores and grades could provide insight into the effects of the change of language. Comparisons involving two nonparametric statistical tests showed that there are no statistically significant differences between the considered generations with respect to success in passing the exam.

For several years now, Python has come to surface as a FPL (Dierbach 2014). Sanders and

Langford (2008) studied students' opinions of Python as a FPL using a survey. Twenty-eight students with no prior programming experience and 27 students with some prior experience completed the survey. Both groups consider Python suitable as a FPL; however, some students with prior programming knowledge are reluctant to move to new languages. Leping et al. (2009) analyze the reasons for deciding to move from Java to Python, after a small-scale experiment on using Python as a FPL with 25% of the students. Python is a multi-paradigm language with a simple and clear syntax, while its popularity in the private sector is growing. Yadin (2011) carried out an action research with the aim of reducing the high dropout rates of students after introductory programming courses. Using Python as a FPL was an important factor, since its simple syntax helped students concentrate on problem solving and algorithms. Other contributing factors were using a visualization environment (microworld) and individual assignments. These factors in combination reduced the failing students by 77%.

So, the most popular programming languages in academia nowadays include C/C++, Java, and recently Python with significantly less represented alternatives ranging from specialized languages such as Matlab to C#, Haskell, PHP, or ECMA Script (Rabai et al. 2015). One of the reasons for the popularity of Python which contributes to its growing use is its multiparadigm approach (procedural, OO, and functional) being gradually more important to reflect in the selection of FPL. Due to fast growing popularity of powerful frameworks and easy web, cloud, and IoT development, another language – ECMA Script – is getting more popular also as a FPL. It is valid particularly for informal learning where developers can “learn by doing” when working usually in a team of more experienced developers.

Teachers' Perspective on the Choice of the First Programming Language

Educators and researchers agree that different factors and concerns (Ali and Smith 2014)

influence the choice of the FPL, as well as that the selection of the FPL has to be reconsidered from time to time based on both didactical/pedagogical issues and technological trends. The literature on this issue falls mainly into two categories: characteristics that a FPL should have; and criteria for selecting a FPL.

A typical example of a paper making suggestions for an ideal FPL is that of Kaplan (2010). Kaplan makes the following suggestions for an FPL in order for it to promote success in creating new programmers: it must support the teaching of the foundational concepts of computer science; it must enable the novice to learn the aforementioned concepts without interference from the details of the programming language; the feeling of competence and liking the practice of programming should be cultivated; and it should incorporate some of the notions of problem solving by design and support the transfer of an algorithm to the programming language. It is clear that these features are usually present in the so-called educational programming languages.

When it comes to selecting an FPL, the most complete list of criteria that could be taken into account is provided by Parker et al. (2006). The complete list of categories of criteria and the specific criteria falling in each category is presented in Table 1. Assigning of weights to each of these selection criteria based on their relative importance in the selection process can help in scoring various potential FPLs for an introductory programming course and making an informed choice.

When it comes to our institutions the factors that have influenced mostly the choice of the FPL, more or less, are the following: the popularity of the PL in industry; feedback from industry partners; programming languages used in competitive study programs; students' and their parents' concerns with respect to employability; the needs of the research labs at the Faculty; availability of good quality development tools and didactical material for the PL; and community support. However, the most important factor for selecting or changing the current FPL are its educational aspects or at least the ability to support students in

First Programming Language in Introductory Programming Courses, Role of, Table 1 Criteria for selecting an FPL (Parker et al. 2006)

Category	Criteria
Software cost	Reasonable financial cost for setting up the teaching environment Availability of student/academic version
Programming language acceptance in academia	Academic acceptance Availability of textbooks
Programming language industry penetration	Language's stage in life cycle Industry acceptance Marketability (regional & national) of graduates
Software characteristics	System requirements of student/academic/full version Operating system dependence Open source (versus proprietary)
Student-friendly features	Easy to use development environment Good debugging facilities
Language pedagogical features	Ease-of-learning basic concepts Support for safe programming Advanced features for subsequent programming courses
Language intent	Full-featured language (versus scripting) Support of web development
Language design	Real or customized Support for target application domain (such as scientific or business)
Language paradigm	Methodology or paradigm Support for teaching approach (function first, object first or object early)
Language support and required training	Availability of support Training required for instructors and support staff
Student experience	Anticipated programming experience level for incoming students

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learning the FPL with specially designed educational programming environments and tools, as well as with applying teaching approaches that have proven to be effective for teaching and learning programming. In any case, the selection of the FPL is usually based on the proposals from the instructors of the corresponding courses and has to be carefully justified in order to be approved by the academic council that is responsible in each institution (such as Faculty assembly, Chair of the Faculty and so on).

Students' Perspective on the First Programming Language

In order to investigate what students think and how they perceive the introductory programming courses and the programming languages used in their context in our institutions, a questionnaire

survey (Xinogalos et al. 2018) has been carried out. The most important information for this study is presented in Table 2.

The main conclusions regarding the cognitive capabilities of the C and Pascal groups and mainly their perceptions on the FPL can be summarized as follows:

Cognitive Capabilities of the C and Pascal Groups

The students learning the basics of programming in Pascal-like languages possess the same cognitive characteristics as the students learning the basics of programming in C-like languages, in terms of their abilities to theoretically understand structures of imperative programming style and develop algorithms for solving programming problems. More specifically, students from both groups perceive the difficulty to theoretically understand structures of imperative

First Programming Language in Introductory Programming Courses, Role of, Table 2 Information for the study on students' perceptions for the FPL

Participants	90 students from University of Macedonia, Greece 87 students from Masaryk University, Czech Republic 111 students from University of Novi Sad, Serbia 288 students in total
Questionnaire	27 questions separated in two parts <i>Questions of the first part:</i> Content, difficulty, quality, organization, and contribution of the introductory programming course. <i>Questions of the second part:</i> Difficulty of learning the programming language used in the introductory programming course; installing and using related programming environments; solving concrete programming problems in that language; students' abilities to theoretically understand programming structures and conceptualize algorithms for solving programming problems. <i>Five-point Likert scale was used:</i> Not at all (1) /slightly (2) /averagely (3) /much (4) /very much (5).
Classification of students in groups	Students were classified in two groups: (1) students that learned basics of programming in a C-like programming language (2) students that learned basics of programming in a Pascal-like programming language <i>Group 1: C or C-like as an FPL</i> - 90 students from the University of Macedonia (C was used as an FPL) - 82 students from the University of Masaryk (C or Java was used as an FPL) - <i>Total:</i> 172 students. <i>Group 2: Pascal-like as an FPL</i> - 111 students from the University of Novi sad (Modula-2 was used as an FPL) - 5 students from the University of Masaryk (Pascal was used as an FPL) - <i>Total:</i> 116 students.
Statistical analysis	For each Likert-type question from the first part of the questionnaire basic descriptive statistics of students' responses per institutional group were computed: The median (the central tendency of answers), and inter-quartile range (IQR, a measure of the variability of answers expressed as the difference between the third and the first quartile). Nonparametric tests were used for comparing the opinions of the two groups of students in relation to the difficulty of learning programming. The ultimate goal was to determine which language class is more appropriate for introductory programming courses from students' perspective.

programming style as easy, while understanding of programming problems and conceiving an algorithm for a particular problem are perceived as activities of medium difficulty.

Installing and Using Programming Environments

Based on the results of the questionnaire there are no statistically significant differences between students from different groups with respect to the difficulty to install programming environments that are used in their introductory programming courses. However, a statistically significant difference was recorded in terms of using the programming environment that is perceived to be more difficult for the C group.

Difficulties in Learning a Programming Language and Using It for Problem Solving

There are no statistically significant differences between the two groups of students with respect to the degree of difficulty in learning the syntax and semantics of the introductory programming language, implementing an algorithm in the language, and correcting syntactical and semantic errors in their own programs. All the aforementioned tasks are characterized as easy. On the other hand, problem decomposition into functions/procedures and finding semantic errors (bugs) in programs are perceived by both groups as activities of medium difficulty.

Since the compared groups of students have the same cognitive characteristics, it can be

finally concluded that the choice of the introductory programming language does not have a deep impact on difficulties that novice students may experience when learning the basics of programming.

Of course, it is important to note that the aforementioned results regarding students' perceptions on the FPL were recorded in the context of three different introductory programming courses that were positively evaluated by students in relation to their content, organization, and quality. More specifically, the students that participated in this study (based on their replies in the questionnaire utilized):

- Considered the contents and the balance between the theoretical and practical aspects of all three courses as highly appropriate.
- Evaluated positively the quality, organization, and contribution of the introductory programming courses they attended.

It seems that the FPL is not the most important factor for students learning the basics of programming. It is the overall quality of the course and the instructors that make the difference. This might explain the results of similar studies reviewed in section "[Review of Research on the Effects of the First Programming Language](#)" that showed no statistical difference in students' performance when some instructors changed the FPL utilized in their courses. Whatever the FPL is, instructors have to work hard in order to make the learning of programming concepts easier for students.

Conclusions

The role of the FPL in introductory programming courses has attracted a lot of research interest for several decades and has been an issue of controversy for teachers and educators. Numerous articles have been published in the literature, and it is certain that many more articles on this issue are on the road. It is quite clear that ideally an educational programming language should be used for teaching an introductory programming course

utilizing an educational programming environment that supports students in dealing with the difficulties of programming that have been extensively studied in the literature. Several teachers believe that once a student has acquired solid foundations in a programming language, it is afterwards quite easy to move to other programming languages. However, when it comes to Higher Education, there are several factors that might not allow utilizing an educational language as an FPL, such as pressure from the industry and students/parents willingness to align with the software industry. Research has shown that utilizing a conventional programming language as an FPL in Higher Education is not as catastrophic as might be expected from the point of view of different educational stakeholders. The accumulated knowledge on students' difficulties when introduced to programming, the various advantages of utilizing Technology Enhanced Learning (TEL) approaches in programming courses (Educational Programming Environments, Intelligent Tutoring systems, Learning Management Systems), and generally teachers' informed choices on delivering a contemporary introductory programming course can alleviate the drawbacks of utilizing a noneducational programming language as an FPL.

Cross-References

- [Programming Language Selection for University Courses](#)
- [Programming Languages for University Courses](#)
- [Teaching Computer Languages in Universities](#)
- [Technology-Enhanced Learning in Programming Courses, Role of](#)

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Flexible and Distance Learning

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Synonyms

Distance education; E-learning; Flexible education; Online learning; Technology enabled teaching and learning

Introduction

Digital technologies can change major aspects of our lives including communication, socialization, and learning. The use of technology for learning in today's world may seem a relatively recent phenomenon. It may come as a surprise to learn that the use of technology in flexible and distance contexts is not new. Fields of study that encompass distance education, online learning, human-computer interaction, and computer-supported collaborative learning have all contributed to a rapidly growing body of research that seeks to understand the experiences and behaviors of learners and faculty in technology enabled learning environments. Research to date demonstrates that the effective use of digital technologies in distance and flexible contexts is a complex endeavor.

Distance and flexible learning has a rich history that dates back decades. Findings from this considerable body of research have led to new ways of understanding the learning process that are distinct from learning that occurs in place-based, face-to-face situations such as the traditional classroom or lecture theatre. This new knowledge, in turn, has resulted in new pedagogies and theories that help those teaching in flexible and distance learning situations to understand and address the needs of learners. What follows is a necessarily brief review of the generations of distance and flexible learning, notable frameworks, influential theories and pedagogies,

technological affordances that support distance and flexible learning, and challenges associated with flexible and distance learning.

Distance Learning

As the use of technology for learning has grown exponentially, the terminology to describe its use has multiplied. Terms such as distance learning, online learning, e-learning, and technology-enabled learning, are just some of the terms used to describe the application of technology in educational settings without necessarily defining exactly what each means. E-learning, for example, is a broad term frequently used to describe any type of learning environment that incorporates digital resources or that is technology-enhanced or enabled. The term has become so generic that it has lost much of its meaning. The net result is that there are multiple technologies and modes of learning encompassed within the e-learning domain. There is, however, general agreement that distance learning is a subset within the broad e-learning domain.

Distance learning refers to learning that takes place away from the actual physical classroom or campus. Distance learning has a range of potential benefits, primary among them is the ability to overcome the time and location limitations of traditional educational settings (e.g., classroom or campus). Consequently, it offers learners the flexibility to learn at their convenience in any location (e.g., home, office, school, university, café, etc.) in their own time, often at their own pace, without the requirement for face-to-face contact with a teacher. Another benefit of distance learning is improved equity of access. Individuals excluded from education in the past, due to geographic location, personal circumstances, financial constraints, disabilities, or lack of course availability, have more opportunities to participate (Moore and Kearsley 2012). Today, distance learning is generally equated with fully online learning – that is, learning that occurs entirely on the internet.

Flexible learning expands the choices available to individuals about what, when, and how they learn. The guiding principle of flexible

learning is learner choice over various aspects of their learning experience. Examples of flexibility include time, place, content, entry requirements, instructional approaches, learning resources, technology used, and communication channels. Flexible learning offers diverse approaches to learning and in doing so supports the needs and interests of learners. Technology use is a central part of flexible learning, but flexible learning encompasses more dimensions than technology alone. Other dimensions of flexible learning include pedagogy, implementation strategies adopted to introduce greater flexibility for learners, and institutional frameworks used to support the provision of flexible learning options across an organization (Collis and Moonen 2001). For the purposes of this entry, flexible and distance learning are considered interrelated with distance learning enabling and enhancing learning flexibility.

Generations of Distance and Flexible Learning

While it not the intention here to provide a detailed account of the history of flexible and distance learning, it is important to recognize that the technological innovations we see today extend knowledge developed from previous generations of distance education. Different generations describe the changes ushered in by various technological developments. The first three generations are frequently characterized as correspondence, broadcast (i.e., radio and television), and computer-mediated (Nipper 1989). While most scholars generally agree about the first two generations, the third and subsequent generations have different approaches. Alternative views of third generation distance learning include those that focused on the technology such as the telelearning model (Taylor 2001), whereas others took a more holistic view that encompassed a systems approach to distance learning (Moore and Kearsley 2012). Fourth and fifth generations of distance learning have also been suggested, linked to flexible learning, enabled via online delivery and aspects of intelligent digital technologies, respectively (Taylor 2001).

The emergence of the first generation of distance learning, correspondence study, involving the use of print-based materials, came about from the need for an educated workforce brought about by the industrial revolution. Factors that contributed to development of successful correspondence study programs included the development of new technologies such as the printing press, low cost pens, and the emergence of a publishing industry, as well as systems that supported the distribution of materials such as the introduction of an inexpensive and dependable postal service and efficient transportation systems (Sumner 2000). During this period, distance education providers emerged who saw correspondence study as a way of providing opportunities to those poorly served by traditional educational institutions.

The second generation of distance education, broadcast, grew out of the development of new communication technologies, advancement of print materials, better quality support services for distance students, and the founding of the Open University of the United Kingdom (UKOU) and mega (distance) universities. This generation did not exclude correspondence instruction, as the emergence of new delivery technologies often embrace those that precede them. However, the broadcast era predominantly involved the use of one-way technologies, namely radio and television broadcasts, along with audio and video cassettes and telephone communication (Sumner 2000). Associations established during this period include the International Council for Open and Distance Education (ICDE) and the Commonwealth of Learning (CoL).

Structured learning materials and predominantly one-way communication from the teacher to learners characterized the first and second generations of distance teaching and learning. Learning was considered an individual process with little, if any, social interaction. Learning models were influenced by behaviorist and cognitive learning theories with the main focus being the acquisition of knowledge (Nipper 1989).

Even though alternate views existed of third and fourth generations of distance learning, the common thread was the potential of conferencing

that added to the strengths of the previous generations. By the early 1990s, the availability of video conferencing, providing both visual and audio connections, allowed two-way, synchronous communication between faculty and students (Taylor 2001). With the advent of computer-mediated distance education, in particular the internet, came facilities such as email, bulletin boards, learning management systems and computer-mediated conferencing (CMC), asynchronous and synchronous, that provided the means for students to interact with faculty and other students in ways not seen in previous generations. Discussion occurred among scholars about whether the internet ushered in a new paradigm of learning because of new modes of delivery (adjunct, blended and fully online and distance), new learning domains (many-to-many communication, place and time-independence), new principles of learning (collaboration and accessibility), and new learning processes and outcomes (high levels of active learning, learner engagement and interaction).

Regardless of whether observed changes reflected a new learning paradigm or not, later generations saw a shift towards more flexible, interactive, collaborative, and constructivist approaches to distance learning. However, the developments of new technology were not solely responsible for the changing approaches to distance learning as progressively constructivist and social constructivist perspectives of learning have become influential and prominent (Anderson 2008b).

Newer generations of distance learning have continued to evolve. Part of the reason for this is that distinctions between traditional (classroom) learning and distance learning are disappearing, with similar technologies used to support learning in a variety of contexts including distance, face-to-face, and blended (a mix of the two) resulting in increased flexibility for learners. The shift towards openness, and the resulting flexibility, in courses, practices and resources that newer technologies can make accessible, have opened up many possibilities for learning to continue across the lifespan (i.e., learning that people engage in throughout their lives). New opportunities

encompass formal learning (e.g., learning that takes place in educational contexts such as tertiary institutions), nonformal learning (e.g., professional learning and development workshops), and informal learning (e.g., pursuing a hobby).

Recent examples of models of flexible and distance learning include MOOCs (massive open online courses) focused on large-scale learner participation that are open and available to anyone who has access to the internet. Platforms include Udacity, edX, and Coursera in the USA and FutureLearn in the United Kingdom, who have developed an extensive suite of offerings. OERs (Open Educational Resources) are any type of educational materials (e.g., textbooks, curricula, lesson plans, videos, assignments) in the public domain that are able to be freely used, copied, adapted, and shared. Examples include: the Massachusetts Institute of Technology (MIT) open courseware; the Kahn Academy, which provides thousands of videos covering a range of curriculum areas including mathematics, science, and history; and the OER commons, an open, curated digital public library platform. These examples (and there are many others) highlight a shift toward flexibility and availability that is increasingly afforded by new digital technologies.

Mobile technologies are also playing an important role in distance learning as they provide the potential to reconfigure and redefine the spaces in which people learn. Mobile learning has a number of characteristics that incorporate learning across time and locations; ubiquitous knowledge access; use of multiple devices; formal, informal, personalized, and social learning; blending of physical and digital worlds; switching between multiple learning activities; and the use of a range of pedagogical models (Wong and Looi 2011). These characteristics point toward increasing flexibility and personalization for learners.

Increasing use of data is the common characteristic of the current generation of distance learning. Learning analytics is an approach adopted by educators and institutions trying to improve student retention and learning experiences by using large amounts of readily available data. Analytics models examine large sets of data looking for patterns that can offer insight to learners, faculty

and support staff who have responsibilities for supporting learners. These models use data from various sources (e.g., student enrolment, demographics, achievement, learning management systems) frequently aggregating them in new ways in an attempt to understand past and present academic performance and to predict future performance (Liu et al. 2017). Insights gained identify students who are at risk of academic failure or dropping out as well as the development of feedback strategies and interventions to mitigate these risks. More recently, learning analytics are assisting the development of more personalized learning approaches with the intention of improving student outcomes.

What the above examples demonstrate is a rapidly evolving and changing landscape of learning generally and distance learning in particular. The potential of technology to promote learning opportunities has never been greater; however, the effective introduction of newer digital technologies into any learning situation is a complex endeavor. As Anderson (2016) argues, “it is imperative, therefore, to identify theoretical constructs to guide technology-enhanced interventions.”

Prominent Theoretical Models and Concepts

Distance and flexible learning has a history of educational theory adoption and development. Constructivist perspectives of learning, in particular the social, situated, and constructed nature of learning, have gained prominence in distance learning (Dyke et al. 2007). Characteristics such as mediation, internalization, cognitive apprenticeship, and distributed intelligence influence the design and development of many distance courses. Emphasis is on the development of online learning communities enabled by digital technologies, creating opportunities for interaction and collaboration through dialogue and discussion.

While it may not be unexpected to discover that well-known educational theories, such as constructivism have been adopted in flexible and

distance learning contexts, new theories and frameworks have emerged that focus on the unique characteristics of learning that occurs both temporally and spatially distant from the teacher and classroom. One of the most well-known is the theory of transactional distance advanced by Moore (2013b) in 1973.

Theory of Transactional Distance

Moore conceived the term *transactional distance* to explain the psychological separation, often experienced by learners, because of the physical and time separation between learners and faculty in distance learning situations. According to the theory, the relationship between the structure and dialogue innate in a learning task determines the degree of “distance” a learner experiences. Structure is associated with the design of a course and indicates the flexibility or inflexibility of adopted teaching approaches, objectives, assessment processes, and so on. Dialogue refers to the amount of interaction between faculty and learners and is associated with the communication medium. According to this theory, low structure and dialogue result in high transactional distance and vice versa. However, high dialogue and structure are difficult to achieve concurrently. While the original theory emerged before the internet was widely available, the idea of transactional distance still resonates with distance learners today.

In addition to structure and dialogue, transactional distance theory includes a third concept, learner autonomy. The larger the transactional distance (i.e., low dialogue and structure), the more responsibility is placed on the learner. Autonomy, in this theory, is synonymous with independence and self-directed learning. The transactional distance model does not suggest that autonomous learners do not need faculty but it does indicate that less dialogue and minimal structure is required when compared with less autonomous learners (Moore 2013b).

Learner Autonomy

Learner autonomy is a central concept in flexible and distance learning; however, the lack of an agreed definition has complicated understanding of what the term encompasses. Some argue that

learner control is a more comprehensive concept than learner autonomy as it addresses the confusion often associated with independence in distance education. Learner control focuses on the opportunities and abilities of learners to influence, and make decisions related to their learning (Anderson 2013). This requires a balance to be struck between independence (learners having the ability to choose freely without restrictions), power/competence (learners taking responsibility for engaging with the required learning), and support (resources, including faculty, available to learners). Support from the teacher enhances learner control rather than reducing it.

Other research has also influenced our understanding of choice, control, and autonomy in distance learning. Some concentrated on control as learner self-direction and identified two types, namely self-direction as: (1) an individual characteristic and (2) the amount of control a learner exerts over his or her learning trajectory. This distinction recognizes that autonomy is both an individual and situational variable indicating that the degree of autonomy a learner expresses can vary across contexts and situations (Anderson 2013). Dron (2007) subsequently developed a transactional control conceptual model. Transactional control focuses on choice and outlines the dynamics of transactional distance. In this model, control is a continuum from teacher control at one end to learner control at the other. Choices made along the learning path influences where a course or learner sits on the continuum. Structure equates to teacher control, dialogue with negotiated control, and autonomy to learner control. In addition to concepts such as independence, control, and self-direction, several studies have demonstrated the importance of learner autonomy, defined as an internal locus of causality and perceptions of freedom and choice over actions, from a motivational perspective (Hartnett 2016).

Community of Inquiry Framework

Another framework that has been influential in the development of understanding flexible and distance learning is the community of inquiry (CoI) framework (Garrison et al. 2000). According to the CoI model, effective learning occurs when

interactions consist of three core elements: cognitive presence, social presence, and teacher presence. Cognitive presence refers to the degree to which learners are able to construct meaning through communication; social presence is associated with the ability of learners to present themselves as “real” to other community members; and teaching presence relates to the design and facilitation of the learning experience including instructional management, the facilitation of knowledge development, and direct instruction. Teaching presence is not always the sole responsibility of faculty and can be adopted by learners who contribute their own knowledge and experiences to build understanding within the learning community (Anderson 2008a). Since the original development of the CoI model, its use and validation has been extensive. Cognitive presence, social presence, and teaching presence have been the focus of research interest.

Recent Theories

Newer theories have also emerged in recent times which have been referred to as “net-aware theories of learning” (Anderson 2016). Net aware theories attempt to understand learning in a connected world where specific affordances of the internet have resulted in abundant access to content and information, massive capacity for communication and the increasing use of autonomous agents, which automate the filtering, aggregating, and synthesizing of content.

One such “net-aware” theory of learning is connectivism (Siemens 2005). The theory of connectivism argues that learning occurs through connections made within networks and the capacity to know more is more important than current knowledge. Importantly, learning can reside outside of the learner within nodes of the network, including learning resources, machines, and other people. Facilitating ongoing learning requires the creation and maintenance of connections. Learning, through the lens of connectivism, is social and knowledge is constructed through interaction and dialogue.

Following on from “net-aware” theories, “network-centric” theories of learning have emerged. These include theories that focus on the network,

theories that focus on social-personal interrelationships and theories that address the design of the network. Connectivism is a well-known example of a theory that focuses on the nature of the network itself. Theories that address social-personal interaction center on the premise that given the changing nature of society and the resulting need for learners to engage in lifelong learning, individuals need to be self-determining in their own learning (Gros 2016).

With the rise of networked learning, heutagogy (the study of self-determined learning) has reemerged as an area of interest and study in the distance and flexible learning field. Essentially, learners are active agents in their own learning and are encouraged to take ownership of their own learning pathway supported by the affordances of web 2.0 technology. In this respect, “network-centric” theories reflect earlier distance learning theories.

Theories that focus on the design of the network generally attempt to provide a theoretical framework from which to consider personal learning environment (PLE) models. Essentially, PLE’s consist of web 2.0 tools and networked technologies that help learners control and manage their own learning. Theories that help describe the design of the network build on other theories such as connectivism.

This section has highlighted that the field of distance and flexible learning is rich in learning theory application and development, whose origin is traced back several decades. This richness is particularly true in contemporary times where the influences of the web and digital technologies are encouraging the emergence of new, network-based theories of learning that build on earlier generations of understanding.

Technological Affordances That Support Distance and Flexible Learning

The use of the internet and related technologies for flexible and distance learning requires approaches that capitalize on the affordances of those technologies. When done effectively,

learning experiences that overcome the challenges associated with distance learning, such as learners’ sense of isolation and issues of persistence, are evident (Moore 2013a).

The term affordance was developed to describe the possible actions or opportunities a particular environment or artefact provides to people (Gibson 1979) that can be inferred from visual or other information that is readily apparent. In other words, an affordance is a characteristic inherent within the object. More recently, the definition of an affordance was expanded to incorporate perceived as well as actual inherent properties of an entity that determine its possible uses (Norman 1988).

The term “affordance” has seen increasing use in education over the last decade or so, particularly in relation to digital technologies. The term has often been used in an attempt to identify and relate the attributes of various technologies to their potential value for learning. The affordance of “communication and interaction,” for example, is reflected in descriptions of web 2.0 (which denoted a second generation of capability encompassing participation and content development (a form of interaction) for educational purposes rather than just content consumption as was previously the case). One well-known affordance of the web is its communication, interaction, and collaboration capability. Examples of digital tools that encompass this affordance include wikis, blogs, and social networking sites (to name a few), which see increasing use in flexible and distance learning contexts.

The web 2.0 example may tend to suggest a kind of technological determinism that views new modes of communication and interaction as actively caused by particular forms of technology. In simple terms, the technology itself determines how humans communicate and interact. This kind of deterministic (one-way) view of technological affordances is somewhat simplistic. Hutchby (2001) offers a more nuanced position that technologies can be viewed as artefacts that “may be both shaped by and shaping of the practices humans use in interaction with, around and through them.” In other words, the affordances

of a technology are not necessarily fixed or predetermined (even if there exists a predominant or prescribed use) but can change depending on a variety of factors including the person using them, the situation, the expertise of the user, their background, and the social, cultural, or learning context.

What this essentially means is that technological affordances need to be considered as part of the learning environment as a whole, of which digital technologies are an integral part, rather than viewing technological affordances in isolation from the context in which they are being used. Another way to think about this is to view digital technologies as having potential affordances which can only be fully understood (and therefore fully utilized for teaching and learning purposes) in the context in which they are being used, taking into account factors that act to promote or constrain them. Furthermore, learners and faculty need to be able to perceive the potential affordances of the technologies and the learning conditions needed to support their expression. This is an important distinction because the actual affordances of specific technologies in distance learning contexts may differ to those in place-based situations for the same technologies.

Several frameworks attempt to identify and categorize digital affordances as they relate to learning. Examples include accessibility, diversity, communication and collaboration, reflection, multimodal and nonlinear, and immediacy. Affordances specific to social software use for learning encompass connectivity, collaboration, content creation and modification, and information aggregation (McLoughlin and Lee 2007). Mobile digital device affordances include responding to the user, handling information, collaboration, audience (access to) which, in turn, can support motivation (McFarlane 2014). It is clear from the different approaches that there are areas of overlap. Of note, is that all of the above identify collaboration as an important affordance of digital technologies.

Collaborative affordances have been further categorized in terms of collaborative opportunities to engage in joint tasks, communicate, share

resources, engage in collaborative learning processes, engage in co-construction, monitor, and regulate learning and find and build groups and communities (Jeong and Hmelo-Silver 2016). This discussion of the various types of technological affordances is by no means exhaustive. Other affordances include learner agency, creative thinking, design thinking, and personalized learning, to name a few. It is also important to note that new digital affordances are likely to emerge and existing ones change as digital technologies evolve and the uses to which learners and faculty put them change.

Interaction and Collaboration in Flexible and Distance Learning

Flexible and distance learning researchers and practitioners recognize the potential of collaborative affordances. A body of research has recognized the importance of online learning communities where opportunities for collaboration and interaction through dialogue and discussion are realized through the use of digital communication tools (Rovai 2002).

Four well-known types of interaction are learner-instructor, learner-content, learner-learner, and learner-interface interaction (Friesen and Kuskis 2013). Learner-instructor interactions are exchanges between learners and the teacher that focus on supporting the motivation and interests of learners. They also offer a feedback channel allowing misunderstandings to be resolved. Types of learner-instructor interactions include establishing learning outcomes, provision of timely feedback, information presentation, monitoring and evaluation of learner progress, facilitation of learning activities and discussions, and determining learners' needs.

Research exploring learner-instructor interactions have resulted in the development of facilitation guidelines (Rovai 2007). These guidelines include strategies for supporting learner motivation that incorporate design principles that integrate learner choice, learning expectations, and online community establishment. Outlining the purpose and relevance of online interactions to learners, making explicit connections to learning

outcomes, and providing appropriate support to encourage participation are further, important considerations.

With the increasing ubiquity of internet access, learners are able to choose from an enormous variety of content and resources. Learner-content interactions identify the intellectual processes that occur between the learner and resources linked to a module of study and are central to distance and flexible learning. Learner-content interactions are evident when learners access textual, audio, graphical, video, and virtual reality representations (Friesen and Kuskis 2013). To interact with content effectively, learners need the skills to access appropriate and relevant resources, which can require content curation from a knowledgeable person such as a faculty member.

Learner-learner interactions describe processes that occur between students studying together. This can include processes such as sharing information and thinking, working together to interpret and complete tasks, solving problems, and sharing opinions or personal insights. Digital communication tools provide distance learners with opportunities to collaborate and actively participate in knowledge co-construction via online discussions (Dyke et al. 2007).

Online communication occurs when learners and faculty use networked technologies to interact and exchange information via synchronous and asynchronous digital tools. Synchronous interactions such as those afforded by web-conferencing tools like Skype, Zoom, Connect, and Google Hangouts allow discussion in real time. Asynchronous communication tools offer more flexibility as they do not require participants to be simultaneously online and allow all community members to have input to a discussion by giving learners time to think and reflect before responding. Communication can occur in the form of text, video, audio, or a combination of these and frequently takes place within discussion fora such as the ones found in learning management systems.

For learners to participate and have positive interactions with peers, they require knowledge and skills to use technology effectively. This

includes having requisite prior knowledge and self-regulation skills. Even with the required skills, peer interactions in distance learning environments are complex and cover a range of intellectual (e.g., reviewing, conceptualizing), social, emotional, and instructional interactions (e.g., analyzing). Analysis of asynchronous peer discussion transcripts has led to a greater understanding of effective peer interactions in distance learning contexts.

The principal mechanism through which an online community is developed and maintained is interaction. Interaction between learners and the development of learning communities are crucial factors in the success or failure of distance courses (Rovai 2002). Developing a supportive network among distance learners can support motivation to learn, commitment to collaborative goals, support co-construction of knowledge, and is significantly related to perceived learning (Rovai 2002). However, developing a network is a complex endeavor. Interaction is an indispensable element of a supportive community but does not occur by providing access to digital communication tools. Class size, course structure, faculty availability, and group facilitation, learners' prior experience, social presence, and personal agency all affect student interaction and perceptions of feeling part of a distance community (Hartnett 2016).

Learner-interface interactions refer to a learner's ability to use the required technological tools to interact and communicate with the teacher, other learners, and the course content. Learner interface interactions mediate all other interactions (Friesen and Kuskis 2013). A relationship exists between a learner's beliefs in their ability to use the required technological tools to learn and their performance within distance learning contexts.

This section has identified that the adoption of constructivist principles that encompass the concepts of collaboration, interaction, and dialogue are important foundations in the development of successful distance learning communities. In the next section, attention focuses on some of the well-known challenges associated with flexible and distance learning.

Challenges Associated with Flexible and Distance Learning

A great deal has been written about the transformative nature of digital technologies, but issues remain, the most fundamental of which is the belief that the technological tools are the transforming influence in distance and flexible learning. This argument has existed in various forms over many years and results from the confounding of the technological tools used with the pedagogy embedded within the design of distance and flexible courses.

At an individual level, the issue of access and affordability results in digital exclusion of some students and can highlight social, economic, and cultural inequality. Retention rates in flexible and distance courses have also been a persistent challenge (when compared with similar face-to-face courses) over the years (Moore 2013a). Feelings of isolation, technical frustrations, lack of requisite prior experience, inadequate technical support, unwilling participation of faculty or students, lack of timely feedback, time constraints, other responsibilities, and low learner motivation are all factors that influence students' decisions to persist or not with distance learning courses (Allen et al. 2013). Furthermore, the size of the group, the formal nature of postings, the effort and stress that can be part of collaborative activities due to issues, such as differences in time zones and language, and study workload can leave students with negative impressions of distance learning (Hartnett 2016). Despite these challenges, meta-analyses of satisfaction research shows students only have a slight preference for face-to-face study compared to distance learning (Allen et al. 2013). Establishing clear learning goals and outcomes, choice and sequencing of content, learner engagement and motivation, interaction (learner-instructor, learner-content, learner-learner, and learner-interface), guidance and feedback strategies, technology access, and selection of technological tools are just some areas that require consideration to ensure well-designed courses meet distance learners' needs (Hartnett 2016).

Faculty, too, face their own challenges when teaching in distance and flexible learning environments. Some institutional leaders have considered distance and flexible learning as a way of increasing productivity and reducing costs, but evidence indicates that more time and effort is required from faculty (Shattuck 2013). Teaching in distance learning contexts requires ongoing learning involving the development of new knowledge, skills, and strategies that encompass both pedagogical expertise as well as technological knowledge. For this to be successful, timely, ongoing professional learning and development, offered at an institutional level, is required along with release time for faculty to develop and apply newly learned skills. In addition to institutional support and ongoing training, faculty participation needs to be recognized and valued at an institutional level. Well-designed institutional policies and procedures are also important as they can act as guidelines for faculty when engaged in course development and online teaching (Shattuck 2013). For example, the burgeoning availability of educational resources requires faculty to be familiar with copyright and usage rights in more depth than required in previous generations of distance education. This example highlights the need for specific guidelines for faculty who are not copyright experts.

Conclusion

This review has briefly explored the different generations of distance and flexible learning, notable frameworks, theories and pedagogies that have emerged, technological affordances that support distance and flexible learning, and challenges associated with flexible and distance learning. What of the future? One thing is clear: it will be different. There are technological advances on the horizon that are set to profoundly influence flexible and distance learning and learning more generally. Innovations such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) are set to reshape the nature of learning. Although a crucial factor, it is easy to overstate

the role of new technologies in the development and transformation of flexible and distance learning practice. It is not simply a question of introducing the latest technology. Pedagogy and technology are interrelated and changing technologies will influence the scope and style of contemporary pedagogies. Therefore, distance faculty need to understand the implications of technology use, within the context of wider society, as they have an essential role to play in preparing learners for the future.

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Flexible Education

- [Flexible and Distance Learning](#)

Formal Models

- [eXtreme Model-Driven Development \(XMDD\) Technologies as a Hands-On Approach to Software Development Without Coding](#)

Formative Assessment

- [Information Technology and Assessment](#)
- [Multimodal Learning Analytics](#)

Formats of Virtual Learning

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Synonyms

[Mobile learning](#); [Online training](#); [Virtual classrooms](#); [Virtual laboratory format](#); [Virtual learning](#); [Virtual learning environment](#); [Virtual reality](#)

Introduction

Since the 1960s, there has been the development of the virtualization of hardware platforms (systems). This ensured simultaneous access to it for many users and operation systems. Today we can speak of the virtual systems independent from each other, in which virtualization of applications (or processes) takes place. It creates some “abstract environment” making virtualization independent of hardware. Currently a lot of special applications for education are developed. Virtual Reality serves as a learning tool. The current human education can be presented in different formats, which is considered in this work.

Virtual worlds in the formats of virtual learning embody abstract knowledge and concepts, quite specific “material” forms, and expressions. The work by Sánchez et al. (2000) presented this idea sufficiently.

The fundamental point, which scientists, pedagogues, and developers must take into consideration, is the idea that Virtual Reality in the human education process is not a passing fad but a universal technology. This technology is intended to improve the process of gaining knowledge, abilities, and skills by trainees. Besides, involvement of students in the virtual learning environment has a positive influence on the process of their socialization and motivational and cognitive sphere of their personal development. If we analyze virtualization of learning process, we see that there are more positive points than negative.

Some models of educational systems of Virtual Reality are presented in different studies in the sphere of informatization and electronic learning.

The works by Whitelock et al. (2000) describe exciting opportunities for users for entering new worlds using the Virtual Reality system. The experience of the practical use of Virtual Reality at school is described in the works by Lang (2004), Dipietro (2010), and Toppin and Toppin (2016).

Virtualization in mobile learning is described in the articles by Ikram et al. (2015) and Harley et al. (2016).

This article considers some formats of virtual learning, which have been used in theoretical and

practical training of university students. The developed formats have had a positive influence on developing the students' knowledge and learning outcomes. The described learning formats proved that virtual learning really broadens the scope of educating people of different social status and position, studying in different countries. Besides, some forward-looking formats of Virtual Learning are presented, working at which enables to improve the education process further.

Emergence of Virtual Reality: History and Survey

Ideas of Virtual Reality appeared as early as antiquity and fascinated many prominent people for most of humankind's existence. It is worth recalling Johannes Duns Scotus, a medieval Scottish theologian, philosopher, and schoolman, who asserted the existence of matter or its reality regardless of the form, which defined only the quality of physical being. The existence of "some" reality was also of concern to the monk Gaunilo from Marmoutier who in his book *In Behalf of the Fool* constructed an ontological argument for the existence of reality in our imagination. He invited his readers to think of the greatest, or most perfect, conceivable island. It is likely that no such island actually exists. However, his argument was the following: "We aren't thinking of the greatest conceivable island, because the most conceivable island would exist, as well as having all those other desirable properties. Since we can conceive of this greatest or most perfect conceivable island, then it must exist."

If at the time of Gaunilo these arguments seemed absurd, then today it is possible to create such reality using twenty-first century technology.

The idea of the very first human immersion in the artificial world belongs to Morton Heilig. In 1960 Heilig opened a cinema with special moving armchairs, different potpourri scents, speakers for playing back sound, and a special screen. Using all these in his cinema, Morton succeeded in giving spectators a sense of artificially created scenery such as a noise, a wind, and even some scents.

Heilig's construction gave start and the future to Virtual Reality.

The main problem of the twentieth century is the creation of the artificial world where a living organism can successfully coexist with the machine. Therefore there appears a human-machine interface.

From "timid steps" in the sphere of entertainment, Virtual Reality enters the process of educating and teaching.

Modern education is a distance education with a complex virtual training technology of teaching. The use of virtual education technology is presented in the works of the scientists who share their working experience in this field.

Education and Information Technology of the Twenty-First Century

The modern world is characterized by transformation of the modern society, in which computerization and informatization are integrated as key tendencies.

Introduction of modern information and communication systems (electronic mail, electronic teleconferences, electronic and information resources with text, visual, audio, and video information) and Virtual Reality technology (Daydream, Vive VR, virtual game technology) turns the latter into a mass product. Virtual Reality as an abstract phenomenon in some way and at the same time having a certain product is widely used practically in all the spheres of the human society. The application of modern information and communication technology (ICT) and technology of Virtual Reality to the theory and practice of higher education creates objective conditions for the interactive communication of international education participants using LMS and for the development and introduction of the system of the professional training of specialists in the virtual educational environment of a higher education institution (Kerimbayev et al. 2017).

Humanity is progressing and is on its way towards technological progress. It is increasingly difficult for the human memory to keep a growing

body of information, knowledge, and skills. While information changes a new knowledge of changing abilities and skills needed for one or another sphere of human activity is required. It implies the need for such form of education, which would help gain these skills while remaining in main professional activity, or even creating conditions of virtual assistance and simulation, and immersing in the specific environment providing with learning “at a distance” with the effect of being present.

Distance learning is used to provide with such form of knowledge transfer. However, just transmission (postage or using Internet technology) is not sufficient today. Distance learning is enriched by new tools today.

Modern online education uses interactive video, gamification, applications, and explanation of the material in the format of scenarios, simulations and stories, and ready samples with the application of various interactive online teaching methods. Other important technological services are widely included in the education process, such as artificial intelligence, updated Virtual Reality, robots, and voice technology. Voice assistants participate in the learning process and can resume basic concepts of a lecture and carry out a session in the form of “question-answer” before the examination; with their help students can receive notifications of updates or their home tasks.

The distinctive feature of the modern higher education is emergence of virtual universities. The educational process of such learning format widely uses digital technologies. Online learning often becomes a contemporary alternative when students cannot be present at a lesson because of some reasons, for example, a heavy snowfall or a severe frost.

In a context of technological innovations and labor market demands, there arises a necessity of improving prior knowledge, gaining new abilities and skills in the professional environment. Sometimes one needs not a long academic instruction but a short and at the same time proper education providing the required knowledge and abilities. This implied the process of “microfication” of online education, which implied the duration of

training sessions, as well. Here there arises the problem of the teaching material itself, which is also presented in online format. Students usually cannot pay great attention to the material in the text format. A today’s student spends from a few seconds to a few minutes on looking through and studying such material. Such approach is called “snack learning.”

Virtual education uses the concepts of “synchrony” and “asynchrony.” Traditional learning at a school lesson, a university seminar, or lecture is synchronous education. Thus, synchronous education is the education involving teachers and students in an interaction at the same time. We can add that teaching and learning here takes place in the same room, and the participants of the traditional teaching-learning process interact at the same time. Asynchronous education is the form of education independent on a place or time, and the interaction between its subjects can take place at different time. One of the examples of such education is a part-time education. Before, part-time students used to receive educational and methodological material by postage, to use audio and video records and broadcast.

In the modern virtual education, synchronous and asynchronous forms are changed. Synchrony in virtual education is teaching-learning in real time. Means of organizing such education are videoconferences, chats, webinars, and message exchange in real time. Here a tutor has an opportunity to respond to students’ activity, answer their questions, and influence their motivation. Asynchronous education has had a number of technology-driven stages in its development. With the introduction of ICT, asynchronous education has been advanced further. Nowadays on the basis of virtual education, asynchronous education in the form of essays, online tests, MOOC, SCORM, Wiki, etc. is successfully realized. Asynchronous realization of the educational process on the basis of the combination of Internet technology and multimedia courses provides an opportunity to project individual learning pathways, including “a convenient time and convenient place,” with the possibility of modifying learning material and technical solutions. Here,

the results of the activity itself, detection of reasons of achieving them, and the focus on the further optimization can serve as quality criteria. In the asynchronous education, a student is quite free; he/she does not have to sit behind a computer at a scheduled time and work with his/her classmates at the same time. In virtual education students are free to choose between synchronous and asynchronous teaching and learning methods.

Formats of Virtual Training: Definition and Effective Ways of their Use

Online Training as Democratization of Education

The most popular form of distance learning now is online training, or e-learning. Such training is conducted using multimedia and Internet technology.

In 1994 there appeared an interesting, in our view, article by Jeff Graham, Tom Alloway, and Lester Krames in the magazine "Behavior Research Methods, Instruments"; it is "Sniffy, the virtual rat: Simulated operant conditioning." The article shared experience in using the operant chamber for studying Sniffy rat. Diane Jass Ketelhut in *Journal of Science Education and Technology* (2007) spoke of the multiuser environment in the article "The Impact of Student Self-efficacy on Scientific Inquiry Skills: An Exploratory Investigation in River City, a Multi-user Virtual Environment." In the article "Spatial updating in superimposed real and virtual environments," Xiaolang Irene Wan et al. (2009) studied how people navigate in real and virtual environments. Training in the virtual environment and the experience of such training is quite widely presented within the medical community. Urresti-Gundlach et al. in *BMC Medical Education* (2017) presented the experience of their work in the article "Do virtual patients prepare medical students for the real world? Development and application of a framework to compare a virtual patient collection with population data."

The experience of using various forms of virtual training in a number of articles was summarized. Kerimbayev (2016) in his article noted that

it was important to consider two basic moments, i.e., impact mode of using virtual environment at training process within one faculty of the university, directly at training quality, and what outcomes can be reached therewith. The work significance consists in studying the virtual environment effect instead of traditional educational outlook and online training in pedagogical sphere. He considers virtual (digital) educational resources, their potential adaptation to trainee's personality and realization during academic process at the university. Virtual training at the university is a total of virtual educational resource. Information and educational interaction exists in the process of subjects and objects interrelation. An integration of information and pedagogical technologies takes place in the process of subjects and objects interrelation. Herein training is connected with such human activity spheres as intellectual, cultural, emotional, and social.

The pioneers of experimenting with modern Internet technology are traditional education institutions. There appear a lot of articles revealing different aspects of distance and virtual learning.

The article "Virtual dialogues and exchanges. The social and cognitive dimensions of interactions among students" (2013) by Analia Claudia Chiecher and Danilo Silvio Donolo focuses on the topic of interactions among peers in virtual environments. The analytical approach considers both the cognitive dimension and the social dimension (addressed more recently in the literature) of interactions.

The current state of virtual education and search for answers to the question "How to design the process of virtual education?" is considered in a number of articles: "Supporting the education and well-being of children who are looked-after: what is the role of the virtual school?" by Drew and Banerjee (2018); "Augmented reality as multimedia: the case for situated vocabulary learning" by Marc Ericson C. Santos, Takafumi Taketomi, Goshiro Yamamoto, and others (2016); "Developing a mathematical modeling course in a virtual learning environment" by Orey and Rosa (2018); "Increasing student engagement through virtual interactions: How?" by Christopoulos et al. (2018); and in others articles.

As illustrated by a number of studies and methods of teaching in schools and universities, online education for some indicators leaves behind the traditional attendance-based format. The basic argument for online education and one of its most important features is democratization of the learning process. Online learning makes it possible to remove most of the barriers: geographical, physical, and financial. Students are able to study in their comfort zone, at home, or on the way to work. Besides, they can choose a more convenient time, content, and pace of study. Online education is much cheaper than the classical one; it is even free. At the same time, there are increasing opportunities for higher education institutions, which can have access to those students who cannot attend lessons personally.

Online education using various formats of Virtual Reality provides different categories of persons with an opportunity to acquire new knowledge and skills: parents having small children, people with health problems, full-time employees who would like to change jobs, or those who could not get education at the time. Thus, such type of education as online education providing opportunities to study for different sectors of society and different categories of its persons is a factor of democratization of education.

The availability and openness of knowledge are accompanied by the development of digital technology. Online tools, the formats of Virtual Reality, which offer the largest possible number of people an opportunity to study subjects taught, are developed. Constantly increasing technical opportunities for communication, delivery, and consumption of online content led to the creation of first independent e-learning agents. They are both Moodle for discussions among students and RSS subscription for the dissemination of the material.

In the case of distance learning, students and teachers can be anywhere in the world. And using 3D glasses or helmets, all participants dive into the virtual world. Each of them can create an Avatar image, which can be present in a virtual classroom. Besides, students can listen to lectures and perform individual or group tasks.

On effectiveness, simulation can even exceed a real teaching process since things are speeding up here; the space is concentrated; and, in contrast to reality, it is focused on increasing the amount of the material taught. With a help of simulations, one immerses in learning experiences, in which processes, knowledge, and skills are highlighted clearly, which is impossible to achieve in reality.

Simulations are one of the most effective training formats, since they provide opportunities to experiment, study, and repeatedly use a new knowledge within a safe model. A high-quality simulation helps some trainees and groups of trainees to develop a high level of understanding and to realize how their conclusions and intuitive reactions influence on what happens to the personnel and the institution as a whole. But it is possible only when simulation looks as reality. The participants “coming out of” the simulation should feel truly that they themselves have been in it, not just their characters.

The infrastructure of distance learning consists of organizational and technical solutions on virtual communication. Among means of communication enabling to realize training online, the following common and most available ones can be identified:

- Mobile telephones.
- Discourse via social networks.
- Collaboration under LMS Moodle.

If a student cannot attend lessons for special reasons, we can give him/her an opportunity to do it remotely. For this aim a classroom is to be equipped by a special camera, which surveys in the format of 360° and transmits a panoramic video of the whole classroom. The students attending a lesson remotely will be able to watch what happens in the classroom in the first person (e.g., from their place), to see their classmates, to communicate with their teacher, and to participate in the lesson. Virtual Reality helps remove drawbacks, which can appear during videoconferences or distance lessons, creating the effect of the personal presence. The teacher can see when a student has to “go out of the

classroom” since helmets with built-in light sensors show whether the device is used by somebody or not.

Tools of Virtual Education

For trainees the immersion in the virtual environment is a kind of training in which not only face-to-face meetings are “created,” but which offers various tools for their joint activities.

Online education defines the character of the teaching and learning process, its educational options. Today most students use their smartphones when taking some courses. That is why mobile versions of courses and applications are becoming a necessary requirement.

Web Meetings

This tool includes audio podcasts, record keeping, handling of archives, a joint work with a desktop, software for painting and drawing, and chats as well. The *format of video lectures* is convenient in distance learning for gaining more knowledge on a profession or for developing professional skills. A video lecture is the video record of the lecture material including fragments demonstrating a subject under study. Students are able to look through the material at their convenience. *Webinars* are “virtual” seminars organized through IT; they represent a remote mode of training in the form of videoconferences and virtual lessons. This system enables to hold videoconferences, talks, interviews, and teaching in real time. Videoconferences represent training in groups; here students can interact with an instructor in the “question-answer” format and listen to a lecture material. Training is organized via special programs supporting multichannel communication (Skype). The webinar format is widely used in distance learning within interactive lectures and seminars. Such kind of training combines an opportunity to cover a big audience and interactive engagement of users and teachers.

Virtual Classrooms

Virtual classrooms enable to organize content libraries; thematic archives; testing on the material studied; surveys of students’ knowledge, abilities, and skills; and assessment tools.

Open online courses enable to study a certain discipline remotely or to improve professional skills. As supplements to traditional materials of a training course, such as video, reading, and homework, massive open online courses provide an opportunity to use users’ interactive forums.

Online courses enable students to gain required credit points while studying in universities – partners. Universities and colleges offer mixed or hybrid programs, in which standard “alive” lectures are combined with working online. Thus, one can attend lessons remotely, i.e., connecting to a translation in real time (synchronous operation) or listening to the recordings (asynchronous operation); a course can include Skype sessions and webinars.

Educational institutions are working at developing massive open online courses (MOOC). Today such courses on special MOOC platforms present the fastest developing sector of distance learning.

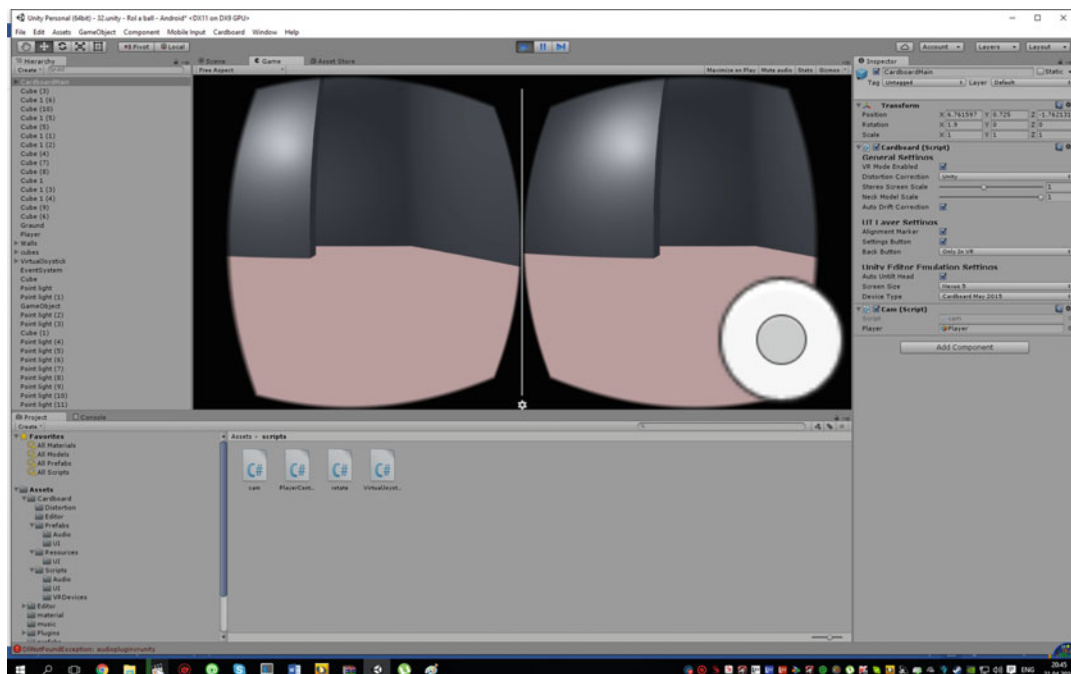
Virtual Learning Environment

Virtual learning environment is a standing environment on the browser platform. It provides an easy access to information, thematic experts, and colleagues in real time. Such tools are used for the integration of informal and formal education based on simultaneous use of video and audio podcasts, virtual classrooms, web-based resources, and social networks into common educational space.

Simulators are used in the virtual learning environment. The traditional approach to learning is expected to change to full gamification, flexibility and the use of the latest technologies for better and full understanding of the gained knowledge. One of such tools is Dialog Simulator format with elements of gamification.

An example is the “Maze,” an educational virtual game with the support of 3D glasses (Fig. 1). In the game one must find the exit from the maze and gather 12 keys. Performing required actions a player develops his attention, motor skills, and spatial orientation.

Along with Virtual Reality (VR), it is better to use augmented reality (AR). Augmented reality



Formats of Virtual Learning, Fig. 1 Fragment of the software for the virtual game, “Maze”

enriches existing technologies with unique ones and enlarges the horizons of virtual potential.

The Dialog Simulator format is the most effective for learning when one needs to develop practical skills. Dialog Simulator enables to immerse entirely in virtual learning. Dialog Simulator can represent an interactive game simulator with an intricate plot and articulated dialogs. It is perfect for training skills related to communication. It provides more interactivity, fuller involvement, and greater learning efficiency.

Dialog Simulator entirely “plunges” a trainee into history, and it is ideal for training managerial and communicative skills.

An educational game is effective if it is necessary to develop particular professional skills.

The use of interactive cases for teaching is the most effective way for developing required practical skills. Cases enable to train required skills within a safe gaming environment, to analyze mistakes made in the game, and avoid them in real-life situations.

Tests are used for controlling a user’s knowledge both in the process of learning and for

summarizing learning outcomes after studying a certain topic.

The creation of the virtual environment using methods of three-dimensional modeling enables a user to train the practical skills, which require a special training.

The basic objective of the online directory is creation of the single information and conceptual field for all users. Having a great number of users and having to accumulate knowledge base, it is useful to store it in a single place.

WIKI (encyclopedia) is a knowledge base, using which students work independently when they need certain information. The instructor works at granting students’ requests for information providing new articles to the knowledge base. The creation of one’s own knowledge base in the corporate network increases the attendance and the overall training level of employees.

Format of Students’ Direct Communication (Blog, Chat, Forums, Social Networks, Etc.)

Such communication can take place both among students of the same university and among

students from different universities. Such complex inter-institutional system of gaining knowledge works through using distance learning sites of the institutions, which have reciprocal hyperlinks.

The social networks such as “My world” (www.mail.ru), “In contact” (www.vkontakte.ru), which is very popular with youngsters, and “Facebook” (www.facebook.com) can be used as tools of distance learning technologies.

Chats, forums, and conferences in social networks are kinds of virtual communication. Students can organize chats and conferences and create contemporary groups for preparing for exams and discussing some content questions in real time. The participation of a teacher in such chats turns a “vertical” interaction to “horizontal” one; it causes greater confidence among students and contributes to improve the process of acquiring information.

As an example can use “Virtual,” the portal, which introduces a text chat, using which one can communicate during a virtual training course.

Chat supports a great number of simultaneously connected users due to the asynchronous architecture in real time. When one user writes a message, another one receives it immediately. In one chat “room,” several users can communicate simultaneously. During lessons students use chat for discussing the material taught, expressing their opinions and points of view concerning a problem. In order to enjoy a conversation, it certainly should be interesting. Having analyzed interlocutors’ messages, one can make conclusions how well they acquired the material taught.

Social networks help reduce the time spent on notifying trainees of coming events in the learning process. It becomes possible to counsel lesson bunkers and lesser students, since they can be reached more frequently in social networks than in classrooms. Communication can take place through comments in discussions and real-time messages among those participants who are online at the moment. Communication in social networks has a number of advantages; one of them is that students communicate in informal environment when a student can ask questions to a teacher without being afraid of looking unaware

of the answer to a question. Today youngsters spend a lot of time in social networks, and their communication along with the possibility to gain knowledge through social networks is becoming a familiar and pleasant experience for them, which results on more effective acquirement of learning material.

The use of a social network will be effective if a teacher places a link to a distance learning site on his/her (teacher’s) site as an additional learning resource.

Thus, thanks to using educational sites and social networks, students adapt easier when they study a new discipline, since they enter a specific information environment, which is created by their teacher, save time for searching for new information, and can get their home task at their convenience.

Virtual Laboratory Format

Virtual laboratory is the software-hardware complex enabling to experiment without reality. A virtual laboratory can be accessed via a computer, including the Internet. A virtual laboratory enables to replace real laboratory studies by math modeling of the processes under study with a virtual interaction of a student with laboratory facilities. The possibilities provided by modern imitational computer models create a perfect illusion of working with real equipment. A virtual laboratory makes it possible to observe periods of physical or chemical phenomena, which are impossible to see in real time, and to model processes, which are impossible in the real laboratory.

Thanks to the virtual laboratory, it is possible to examine processes in details and observe what is taking place in different time scale, which is relevant to the processes taking a fraction of a second or, on the contrary, lasting for several years. An important advantage of the use of virtual laboratories is safety when working, for example, with high voltage or with chemicals. Since a computer manages a virtual process, it is possible to quickly conduct a series of experiments with different values of input parameters, which is often necessary for correlating output parameters with input ones.

The disadvantage of a real laboratory is the problem of inputting gained information to the

computer. There is not such need in a virtual laboratory, since data can be saved in the electronic results table directly with experimenting by an experimenter or automatically. Therefore, time is saved and the number of possible mistakes decreases.

Virtual Reality Format in Mobile Learning

Today almost all people have mobile devices, mobile phones, or tablets, including even very young children. While children mostly use them for playing, adults use them as an “information navigator”: they read news, map routs, seek contact information, etc. The diversity of the consumed content has one similarity, its relevance. Taking a smartphone we search for the information, which we need here and now, which is exact and sufficient.

Mobile learning must also be relevant in this regard. Mobile devices enable to organize learning independently of the location and time. Most mobile devices have built-in sensors or special applications, which can, for instance, recognize a voice, have location services, and can measure the speed and direction of their owners and even their biorhythms.

We, for example, have developed a pulse sensor. It is a tiny programmable heart rate monitor, which triggers the alarm at the doctor’s phone when the patient’s heart rate is slow (Fig. 2).

Data of mobile analytics of using educational systems, sites, and applications, combined with a

user’s physiological, geolocation-based and other personal data, offer great prospects for creating a personalized system of e-learning. Today new technologies combine the potentials of networks, smartphones, messengers, and online maps.

The implementation of mobile learning has been possible by a broad set of functions of modern mobile devices, which today include voice communications, messaging, graph sharing, Internet browsers, and others.

There are increasing opportunities of social networks in the sphere of Virtual Reality. An interactive telephone conference can be held among several friends. Users can “meet” in 3D virtual world connecting headphones to their telephones.

The system of mobile learning in Virtual Reality solves such urgent problem as realization of a high degree of trainees’ socialization, development of their communicative competences, and the ability to work as a team.

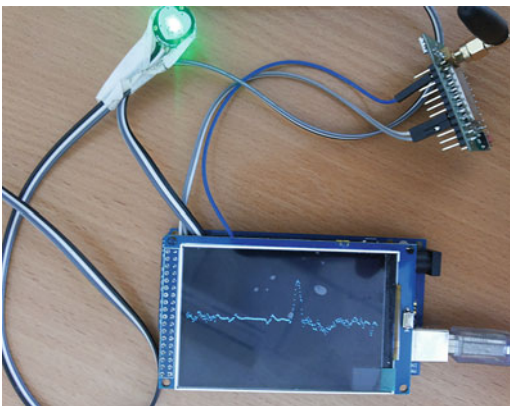
Mobile learning with the use of Virtual Reality requires the development of mobile applications. Such mobile applications should have certain functions enabling to perform various actions.

Referring to mobile applications for education, it is worth mentioning their possibility of accessing cloud services, which are used as a single information field for storing the information of students and teachers and indicators of learning and teaching activities.

Cloud Format

Cloud is a model of online repository, in which data is stored and processed in virtual server. Physically such servers can be located geographically remotely one from another. Besides, this format enables to hold a so-called cloud videoconference. Connection via videoconference requires relevant equipment, software, and a team of experts. But the emergence of the “cloud-related solution” allows avoiding these requirements.

During a cloud videoconference, users are physically present anywhere in the world; the main thing is access to the Internet. Besides, thousands of users can participate in the same videoconference simultaneously. It is quite easy: an



Formats of Virtual Learning, Fig. 2 Hardware implementation of the heart rate monitor, “pulse sensor”

initiator inputs the title and the time of a conference, sends invitation to users via e-mail, clicks at the link in the browser, and becomes the conference participant.

The study undertaken in this area suggests that students consider virtual learning efficient and even more qualified than the traditional education.

Virtual Reality (VR) Promising Formats and Disadvantages of Introducing VR into Education

Virtual worlds are the most complicated and the most promising tools for organizing training. Their use requires very sophisticated software. Such training faces increased requirements for a teaching staff and service personnel. It enables to introduce the most complicated scenarios of informal and formal education. Virtual worlds are the most cost-effective and efficient solutions for organizing distance learning. Virtual learning environment is being implemented in institutions owing to its economy, interactivity, and simplicity of use. It is much more difficult for adult students to adapt to the real learning process. They feel much more confident in a virtual environment. This explains sympathy for virtual environments; besides they focus on the thematic content and are constantly developing technologically.

What opportunities for education does Virtual Reality propose? Today education is considered one of the most promising areas for developing and introducing Virtual Reality technology. The idea of applying Virtual Reality to teaching and learning is not new anymore, and VR technology has been used for a long time, from virtual excursions at History or Geography lessons to training flying a plane or running a bullet train. Virtual Reality provides new opportunities for studying theory and improving practice, since traditional methods can be rather costly or too complicated.

There are five basic advantages of using VR in the education sector.

- **Visibility.** 3D graphics enables to reproduce the detail of even most complex processes invisible to the human eye, up to the decomposition of nucleus or chemical reactions.

Besides, nothing prevents from improving the level of detail in order to see the movement of electrons or to reproduce, for instance, a mechanical model of the development of a human body's cell at different stages. Virtual Reality enables to reproduce or model any processes or phenomena known to contemporary science.

- **Safety.** Practical fundamentals of piloting aircrafts and jet planes can be perfectly safely mastered at a VR device. Besides, VR enables to train too complicated medical operations or manipulations without harming the humans or putting them at risk.
- **Involvement.** VR technologies enable to model any mechanics of activities or behavior of an object, to solve complicated mathematical problems in the form of games, etc. Virtual Reality enables to travel in time looking through main scenarios of important historical events or to see the inside of humans at the level of the movement of red blood cells.
- **Focusing.** A space modeled in VR can be easily examined in 360° panoramic view not distracted by external factors.
- **Possibility of conducting virtual lectures.** Thanks to the option for displaying a modeled first-person space and the effect of one's own participation in virtual events, it has made possible to conduct different types of lessons in Virtual Reality mode.

Let us consider what advantages and disadvantages learning in Virtual Reality mode has.

Formats of VR in education trigger the process of gaining required material. Besides being able to read or listen of the most extraordinary experiments, trainees can see them before their eyes. Virtual Reality technology provides excellent opportunities for acquiring an empirical material. The traditional lesson format remains almost unchanged; it is only supplemented by the immersion into VR for 5–10 min. It is possible to divide one lesson into several stages, in each of which the most complicated moments are visualized in the virtual world. As before the basis of the presentation of a new material remains a lecture. But

Virtual Reality enables to improve a lesson by involving students in full immersion in learning process visualizing key moments of the material covered. When learning in Virtual Reality mode, the efficiency, the level of memorizing information, and the interest in learning increase. VR technology offers opportunities to model any situations, including emergency, which are difficult or impossible to realize when learning in real life; there is no necessity to take any risk of being injured, as, e.g., through handling high-risk equipment; there is no necessity for a trainee to be present at hazardous establishments; there is no risk of damaging real equipment when learning; VR simulators are cheaper than complex and cumbersome life-size training devices, which have to be bought and installed.

At the present stage, the newest models of VR devices have not yet been developed perfectly for their full application in order to teach at school or university; therefore, the potential use of Virtual Reality has a number of disadvantages.

- Workload and labor intensity. Almost every subject has a large amount of an important material; therefore, the creation of one such course requires a lot of work for creating a virtual content. It can be both a specific lesson on each topic and dozens of specific applications. The companies, which plan to work on developing lessons in Virtual Reality mode, have to be prepared to the fact that this process will take a lot of time and resources without the possibility to make a profit until a proper lesson or a complete course consisting of several lessons is developed.
- Cost of equipment. In the case of distance learning, students need to be concerned about accessing gadgets able to visualize Virtual Reality; besides, educational institutions need to purchase an expensive equipment for the classrooms, where virtual lessons are conducted, which requires a lot of money.
- Functionality. Like any other similar technology, Virtual Reality needs to use its own language. In order to create a perfect virtual lesson, one needs to choose proper tools.

- Existing applications of Virtual Reality for education cannot take advantage of all potential of the technology and, therefore, do not perform their core functions.

Virtual Reality technology can be applied to education, and most likely in the near future, we will be able to witness a real breakthrough in this area and numerous interesting discoveries.

Conclusion

Prospects for the development of virtual learning are that in the future, such type of education will become usual and content-oriented. As an integral component of the universal social educational structure, this type of tutoring will become more useful and widespread. It will affect virtual education of the future. It will become even more available and informative and enable more people to participate in the process of gaining knowledge. However, it will not be able to completely displace more common for us form of learning. Technologies of virtual communication will be approaching to modeling its real analogue with time.

Cross-References

- [Adoption of Virtual Laboratories in India, Learning Assessments and Roles of ICT Skill Learning Tools](#)

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Game-Based Learning

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Synonyms

[Edutainment](#)

Definition

Digital game-based learning (DGBL) is increasingly being used to refer to the use of games for expected learning outcomes. The expression emphasizes the importance of the context of using digital games for educational purpose rather than the use of stand-alone applications (Egenfeldt-Nielsen et al. [2011](#)). Game-based learning (GBL) usually refers to the use of digital games called serious games, digital learning, or educational games. However, non-digital games are also widely used for educational purposes. GBL is not often clearly defined in research papers. This is probably due to the difficulty to defining what playing means. Two main criteria emerge (Brougère [2000](#)). The first criteria is the second-degree, the meta-level of the activity. A same conduct might be considered to be a game or not depending on the meaning of the activity. As a consequence, a game is frivolous and nonproductive. The second criteria consist of the

autonomy of the player. He/she is allowed to take his/her own decisions and to shape his/her decision. This autonomy is framed by rules and uncertainty always remains in regard to the ending. A core characteristic of a game is its agonistic dimension. A game is an artificial conflict (Salen and Zimmerman [2004](#)) where a player competes with the game itself or opponents.

DGBL is a complex educational practice. It includes a large variety of games and gameplays, subjects and disciplines, formal and non-formal educational contexts, school levels, and also a variety of teaching, training, or other educational practices. In addition, DGBL does not only refer to the use of a specific game for expected learning outcomes. DGBL also refers to a learning scenario where playing is important, but is not limited to the use of a game. In particular, DGBL includes debriefing that is recognized important for the metacognition and the transfer of knowledge.

DGBL is close to gamification of learning contexts. However, while gamification refers to the implementation of motivational affordances in non-gaming educational contexts, DGBL refers to the use of a specific game, called serious games, educational game, or learning game for expected learning outcomes.

Introduction

The usage of games for educational purposes is not a new idea. Already, in the Greco-Roman

world, Plato, Aristo, and Quintilius valued the contribution of play to the moral and physical child's development. In Greek, *paidia* (play) and *paideia* (education) have the same roots. In Latin *ludus* means both game and school. The idea that playing might have an educational value came back during the humanist area after a long period in which playing has been mostly rejected. Later on, in Europe, Fröbel (1782–1852), a German pedagogue, played an important role in spreading the idea that play might have an educational value. However, game-based learning has been mainly restricted to nursery school for a long time. Play is recognized to be important for child development (Piaget 1945); however, this idea has been challenged by Sutton-Smith in a book published in 1997, *The Ambiguity of Play*. Sutton-Smith underlines that there is rhetoric of play as progress, which poses play as a developmental arena, not supported by evidences but by values and ideologies.

The development of digital technologies that enable game design in various fields offers new opportunities for teaching and learning and digital video games were already employed in the 1970s (Egenfeldt-Nielsen et al. 2011). Today, digital game-based learning (DGBL) attracts more and more attention from educators and educational researchers. Learning games are now used in primary and secondary schools and also for vocational education. DGBL is used at university and by companies for training professionals. Persuasive games are also used by activists, politicians, and institutions. As a result, more and more research projects try to assess the educational value of learning games or to understand how playing is connected to learning.

DGBL is grounded on different educational theories. In a meta-analysis, Wu et al. (2012) distinguish DBGL based on behaviorism. Learning is considered to be produced by stimulation and reinforcement due to the feedbacks provided by the game. For cognitivists, DGBL is based on the acquisition of knowledge and growth of the mental structure: information is received, processed, and organized into existing schema. Humanists stress the importance of construction of meaning for learning. They emphasize that DGBL is student centered and personalized and

foster student's motivation. Constructivism and social constructivism consider learning to be an active, constructive, and social process. DGBL is grounded on its situated and experiential feature.

From this complex landscape of GBL, two main approaches emerge. The first approach valuing DGBL is in line with Prensky claims (Prensky 2001) and the concept of edutainment, a form of entertainment designed to be educational. DGBL has its roots in the humanist tradition expressed in *De civilitate morum puerilium*, a handbook written by Erasme (1467–1536). Thus, DGBL is considered to address some of the pitfalls faced by educators such as lack of student's motivation or student's confidence (Egenfeldt-Nielsen et al. 2011). The second one is based on the idea that games might have an intrinsic educational value. This perspective is more in line with Fröbel's ideas (Brougère 2000) and constructivist and cognitivist theories. According to this approach, the educational value of a learning game is not limited to its power to motivate students but results from the contextualization of knowledge in a challenging situation where the player can assess his/her way of thinking and behaving and develop the needed knowledge to adjust to this situation (Sanchez 2017).

An overview of the main principle of educational theories supporting DGBL is proposed in section “[Toward a Game-Based Learning Theory](#).” In section “[Diversity of Games and Gameplays for Learning](#),” we briefly describe the diversity of learning games and, in section “[Different Uses of Games for Educational Purposes](#),” the diversity of the contexts for their use. Section “[Challenges and Criticisms Leveled](#)” is dedicated to emphasize the challenges faced for the implementation of DGBL and Section “[Current Trends in Research](#)” to current trends in DGBL research.

Toward a Game-Based Learning Theory

Game-Based Learning as Experiential Learning

Game-based learning has close relationships with problem-solving. Indeed, a game is an “artificial conflict” (Salen and Zimmerman 2004), a challenge that must be resolved by the learner. The

learner/player faces an antagonist system composed by the game itself or adversaries (Sanchez 2017). The objectives of the player are antagonized by the resistance of the system, and the game becomes a factor of difficulties and disequilibrium (Balacheff et al. 1997). A conflict arises, and the player/learner takes decisions and shapes strategies based on his/her conception (even misconceptions), and bad decisions are punished with loss of points. Hence, from the player perspective, it demands to shape strategies and to develop the knowledge needed to win (Ibid.). This view of DGBL is line with Piagetian theories. Learning results from the adaptation of the learner to the game and, as a result, from the interactions that emerge within a given situation. Thus, learning from games has close relationships with learning from simulations and microworlds (Papert 1980). DGBL has also been linked with situated learning (Lave and Wenger 1991). For example, the so-called epistemic games (Sanchez et al. 2013; Shaffer 2006) offer the player/learner the opportunity to acting and learning professional practices. The player/learner is supposed to make his/her own discoveries and to learn from trial and error strategies through self-regulated learning. By recognizing inappropriate knowledge, the player/learner revises his/her knowledge and learns from his/her reflection on playing.

As a result, the core concepts of DGBL are interactions and feedbacks. Meaningful feedbacks provided with rewards (points, bonuses, or badges) play the role of a formative assessment. In addition, errors become useful for the learning process and provoke minimized consequences if compared with traditional teaching. These *graceful failures* (Plass et al. 2015) encourage risk-taking and further explorations. In this perspective, game-based learning is grounded on the philosophy of John Dewey and the idea of experiential learning (Dewey 1938).

Games-Based Learning as a Social Practice

Games have also been considered as demarcated universes or *magic circles* (Huizinga 1955) that stimulate a form of social practice. Social practices can take the form of collaboration so that teammates are involved in epistemic interactions (Ohlsson 1995) and learning consists in social

participation (Wenger 1998). Epistemic interaction can involve different interactive processes such as explanation, production of an articulated discourse, elaboration of meaning, or clarification of views (Baker 1999). Teammates extend and make explicit the knowledge needed to address the challenge (ter Vrugte et al. 2015). By doing that, knowledge is developed, discussed, assessed, and shared. However, some authors stress that the positive effect on learning also depends on the epistemic quality of dialogues (Van der Meij et al. 2011).

Avatars have also been recognized to be important for DGBL. When players are represented by an avatar, the avatar plays the role of a projective identity (Gee 2003) in two different meanings. First, avatar is an Indian word which means incarnation. It allows the players to have a self-experience through introjection. The avatar plays the role of a mirror reflecting on his/her own values and choices. For example, he/she is led to check the relevance of the decisions he/she make by getting or losing points. The player immerses into a role, and he/she is protected from the consequences of his/her errors and failures that are assumed by his avatar. Second, the avatar is an emblematic figure which becomes the projection of an identity, an ideal figure in which the player can project his ideas, values, and desires and, therefore, find the opportunity of self-development (Sanchez et al. 2016b).

Context and Teacher's Roles

Numerous meta-analyses are inconclusive regarding the positive or negative effects of DGBL as individual cases could differ widely. Game, as a generic term, is so broad, that it is difficult to compare case studies. In addition, the studies differ in terms of types of games, subjects, integration into learning scenarios, school levels, and contexts for their use.

Depending on school systems, cultural traditions, and educational policies, DGBL might be favored or disfavored. In Europe, different initiatives have been taken for the promotion of DGBL. For example, in 2008, the European Commission launched a program for the development of the use of digital games in school (Pivec and Pivec 2008).

The teacher's role has been recognized as a key factor for a successful implementation of DGBL. Teachers might participate to the game design (Sanchez et al. 2017). They are concerned with the selection of games adapted to their teaching objectives and the design of relevant scenarios. They might play the role of game-masters and use Play Management System designed to support both players and teachers to deliver, use, manage, and track play situations (Sanchez et al. 2016a).

There is a difference between mastering the rules of the game and recognizing the ways those rules structure our perception of reality (Jenkins et al. 2006). Thus, it is important that players/learners become able to evaluate the distance between the game and reality. In addition, learning occurs only after reflection and debriefing (Garris et al. 2002). Debriefing plays different roles for DGBL. First, debriefing fosters reflection and metacognition. The implicit knowledge dedicated to play becomes explicit through an after-playing debating session. Brousseau (Balacheff et al. 1997) terms institutionalization this debriefing session. The word institutionalization stresses that it leads to the change of the status of knowledge. The situated knowledge needed to win the game becomes more universal and is validated by an official external source, the teacher/trainer. Second, debriefing is recognized to be crucial for the transfer of knowledge and the learning experience is undermined if the players are not aware of the learning elements (Egenfeldt-Nielsen 2006). For some authors, the game-learned experience is transferable if the teacher clarifies the purpose of the simulation before using it (Aldrich 2005). However, the concern with debriefing seems to have been lost in a majority of research studies (Crookall 2010).

Diversity of Games and Gameplays for Learning

DGBL consists of the use of a huge diversity of games. All disciplines are concerned; however, business, mathematics, and science seem to be the most common disciplinary subjects addressed.

Some games that were not primarily designed for educational purposes have been adopted by teachers. For example, Civilization (MicroProse), a strategy game in which the player attempts to build an empire, is used to teach history (<https://civilization.com>). SimCity (Maxis), a game in which the challenge consists of founding and developing a city, is used by geography and economy teachers (<http://www.simcity.com>). Some physics teachers also designed learning scenarios for secondary students based on ballistic and mechanics studies with Angry Birds (Rovio Mobile), a game which consists of launching birds with the goal of destroying pigs. Many commercial games adapted to different disciplines have been adopted by teachers. For some of them, there is a specific version dedicated to education (<https://www.angrybirds.com>). SimCity EDU and Microsoft Educational Version of Minecraft launched in 2016 are the most famous of them. In 2017 Ubisoft announced a new version of the game Assassin's Creed Origins tailored for teaching ancient Egypt at school (<https://assassinscreed.ubisoft.com>).

Games primarily designed for learning and training are often referred as educational serious games, educational games, or learning games. They often take the form of video games for computers, iPad, or smartphones. For example, DragonBox is a famous series of educational math apps that are designed to teach algebra to primary students (<http://dragonbox.com>). Mechanica, (Creo) a game about physics for secondary students, and Tamagocours (Sanchez 2017), a game about copyright of educational resources for preservice teachers, have been designed by teams composed of educators, game designers, and researchers (<http://www.mecanika.ca>).

Numerous serious games have also been designed for training professionals such as soldiers (e.g., America's Army (<https://www.americasarmy.com>)) or surgeons (e.g., Touch Surgery (<https://www.touchsurgery.com>)), and the training sector has put considerable effort and money to improve professional training with DGBL. The health sector has also adopted DGBL for professional and patients.

There is also a huge diversity of games in terms of game apparatus and gameplays. The most common games are video games, online video games, or apps for cellphones and tablets. DGBL also encompasses location-based games, role-play games. Since several years, new games attract more and more attention. Alternate reality games enable for the design of complex learning environment that combines physical reality and simulations. During the recent years, teachers have also designed escape games with educational content. S'CAPE, an online platform, enables teachers to share their games and to collaborate for designing the games (<http://scape.enepe.fr>).

Different Uses of Games for Educational Purposes

Fostering Motivation and Engagement

Following a humanist tradition, DGBL is often considered to have the power to promote positive attitudes toward disciplines (Ke 2008), to make the learning experience more enjoyable, to foster student's motivation, and to engage students to learn (Dickey 2005; Jabbar and Felicia 2015). The main reasons that are evoked are grounded in the self-determination theory (Ryan and Deci 2000). Games are known to fulfill innate human psychological needs such as autonomy (freedom framed by rules), self-confidence (game levels that promote successes), and relatedness (interactions with teammates and adversaries). Flow is also often mentioned. Flow is defined as the highest degree of motivation by being completely involved in an activity for its own sake (Csikszentmihalyi 1990). However, engagement in games is not only related to elements inherent in games. It depends, as well, to the attributes of players such as motivation to play, playing styles, ages, or gender (Connolly et al. 2012).

Drill and Practice: Games for Training

Like simulations, games offer the opportunity to practice in a safe environment. The learner can test different strategies and make mistake without bad consequences. Moreover, bad strategies can be experimented and their outcomes assessed.

Thus, DGBL have been used to train professionals for the development of various competences. One of the most famous examples relates to America's Army which is used for the recruitment and training of soldiers. Serious games are also used to train pilots to handle unknown and unexpected situations (Kuindersma et al. 2017) and teachers to react to school mass shooting (EDGE – Enhanced Dynamic Geo-Social Environment (<https://www.dhs.gov>)).

Different games have also been designed to train professional to interact with customers (*Adoptez la client attitude* !(<http://www.ktm-advance.com>)) or employees (*Entretien Annuel d'Evaluation*¹¹).

Raising Awareness with Persuasive Games

Serious games also realize a new form of rhetoric (Bogost 2007). Thus, some of them have been designed to persuade people to adopt a specific conduct or to change their opinion. They are called persuasive games. For example, there is a huge diversity of games for health that intend to help people to adopt conduct for preventing or treating disease and to develop self-management skills. There are many examples of such games for young diabetics (Times Out) or obese persons (Fat World (<http://www.gamesforchange.org/play/fatworld/>)).

Numerous games are also employed to raise people awareness on social and environmental issues such as fight against terrorism (September 12th (<http://www.gamesforchange.org>)), consequences of the exploitation of oil shale (Fort Mac Money (<http://www.fortmcmoney.com>)), or fast food (McDonalds (<http://molleindustria.org/>)).

All the examples mentioned above elaborate on the idea that a game is a medium that can support or disrupt conducts or social positions through procedural rhetoric, i.e., rule-based representations and interactions (Bogost 2007).

Learning from Creating Games and Modding

In a study published in 2011, Vos et al. (2011) concluded that students involved in creating games demonstrated more cognitive competence than those who just played existing games. Some platforms enables for the creation of games. For

example, Scratch (Resnick et al. 2009) enables young learners to develop computational thinking through the creation of mini games. DGBL can also take the form of modding. Modding consists of the alteration of already existing games. Bayliss (2012) reports on modding the commercial game Minecraft for a course on artificial intelligence.

Assessing Skills with Games

In general, games provide immediate feedbacks to the actions performed by the player/learner. As a result, a game plays the role of a space for reflexivity within which the player can test his ways of behaving because his/her decisions translate into immediate feedback (Sanchez et al. 2016b). Gee and Shaffer (2010) develop a similar idea when they state that we are wrong when we design games for learning; they should be designed for testing, and they are assessment systems (Shaffer 2007). The same authors stress that inherently require and assess a set of twenty-first-century skills. Indeed, the so-called epistemic games (Shaffer 2006) enable for distinguishing between experts and novices than can any standard paper-and-pencil test.

Such an approach has been followed by Renault Trucks, a French company. The company developed a game dedicated to train their employees to interact with customers. Finally, they recognized that the game did not add any value to the training. However the company decided to use the game as an assessment system as it demonstrated its power to assess the skills required to interact with customers.

Information and Media Literacy

Since digital games represent now an economic sector with a more important turnover than the trade of books or music, there is a need to develop game literacy for the young generation (Buckingham and Burn 2007). As a result, games should not be regarded merely as educational tools. Education about games should be taken into account. Indeed, the gaming culture is important for the new generation. In addition, playing a game can become a persuasion to believe in the general ideology surrounding them (Sutton-Smith 1997). Thus, game literacy is a form of media literacy. This issue has been addressed by

teachers. A blog post reports how Pascal Mériaux, a French history teacher, has integrated Assassin's Creed into his course on the French revolution (<https://blogs.microsoft.fr/enseigner-lhistoire-geo-avec-assassins-creed-cest-lidee-geniale-de-ce-professeur-de-lycee/>). Students are asked to discuss the representation of this period by the game.

Challenges and Criticisms Levelled

Digital game-based learning has often faced criticisms and has been called chocolate-covered broccoli approach (Bruckman 1999) or sugar-coating education (Kirriemuir and McFarlane 2004). Disguised educational content is recognized to have a negative effect. These criticisms are in line with Freinet's opinion. Freinet draws a distinction between play-work and work-play. Play-work is free play which can become bad kind of play. Work-play, on the other hand, is real and productive work done by children (Freinet 1946). There is also a non-negligible proportion of students that is reluctant to consider that learning result from playing (Egenfeldt-Nielsen 2007) or who prefer direct instruction. Another criticism levelled is the short-term effect of DGBL. When the novelty of using reward system within games wore off, the learners' engagement decreased (Ronimus et al. 2014).

Thus, the difficult challenge faced by game designers consists of merging gameplay and educational content. The so-called serious games are often designed by educators and not by game designers. They are often poor in terms of playfulness. Others game might be fun but not really educational since the players can address the challenge with no learning gain. Game mechanics should be aligned with the learning goals of the game. Games that manage to combine attractive gameplay and educational content are said to be intrinsic (Habgood 2007).

Current Trends in Research

A majority of current research falls within an essentialist viewpoint on DGBL. The functions of a game are considered resulting from a set of

attributes that might be studied independently. For example, some studies focus on the effect of specific game mechanics like competition (ter Vrugte et al. 2015) or game elements (Filsecker and Hickey 2014). A new research trend is currently emerging. Play is considered to be performative (Sanchez and Mandran 2017) and to depend on the *lusory attitude* of an individual who accepts the arbitrary and artificial rules of the game. This emphasizing of the player is also noticeable in the expression *playful learning* proposed by Plass et al. (2015). Playful learning describes learning that incorporates game elements, even though the learning environment might not be considered a game. Already, in 2007 Mitgutsch advocated for the adoption of the expression play-based learning and thus emphasized the importance of the player. Henriot's work (Henriot 1969, 1989) about game and play is important regarding this question.

Playing analytics, the collection, and analysis of player's interactions with the game during play activity offer new opportunities for the understanding of DGBL. Most of the recent studies are limited to qualitative studies about numbers of players connected, players' clicks on the interface, or needed time for achievement. However, some researchers try to go beyond with players' strategies or error analysis (Sanchez and Mandran 2017). Playing analytics should play an important role for future research into DGBL.

Cross-References

- [Computers in Primary Schools, Educational Games](#)
- [Computers in Secondary Schools, Educational Games](#)
- [Games in Higher Education](#)
- [Games, Simulations, Immersive Environments, and Emerging Technologies](#)
- [Gamification](#)

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Game-Based Learning Environment

► [Computers in Primary Schools, Educational Games](#)

Games in Higher Education

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Synonyms

[Game-based learning](#); [Learning games](#); [Serious game](#); [Simulation games](#)

Introduction

This entry presents an overview of how and why Learning Games are used in higher education.

Learning Games can be defined as games that are designed to captivate the learners' attention and facilitate their learning process. They have explicit educational purposes and can be used for teaching at all levels of education. All types of games can be used for learning: board games, card games, role-playing games, first-person shooter games, simulation games, management games, puzzle games, treasure hunts, etc.

The main characteristic of **Learning Games for higher education** is the fact that they are designed to teach specific complex skills taught at university or during professional training programs. Unfortunately, it is not infrequent to observe strong opposition on the part of this target audience to this mode of learning that these adult students associate with children.

The use of Learning Games in primary school seems natural to teachers and is encouraged by specialists in didactics and neuroscience. This learning technique is much less frequently used in middle school and is almost completely absent

from higher education. Yet teachers at all these levels are faced with the same problems, such as lack of motivation and investment, for which games are known to be an effective solution. This entry presents an overview of the games that can be used for higher education and the reasons why some teachers and students still show resistance to this type of learning. The numerous advantages of games for higher education will then be presented, citing games presently used in universities, in graduate schools, and for professional training. Finally, this entry presents the current research questions that need to be addressed concerning the design of games for higher education and the acceptance of these games by teachers.

Accepting Games in Higher Education

Teaching with Games

As children, we naturally use games as a pedagogical tool to enhance our emotional, sensory, motor, cognitive, intellectual, and social development. This natural process is adopted by teachers in primary schools to teach mathematics, history, art, music, and foreign languages (Kamii and DeVries 1980). This pedagogical approach aims to use game mechanics in order to captivate students' attention and engage them in their own learning process (Dondlinger 2007). When playing, **the learners become the central actors of their learning process**, a role quite unlike the passive position they occupy, most of the time, in traditional education. In order to win the Learning Game, students need to make decisions based on their newly acquired knowledge. Moreover, the **learners find themselves emotionally engaged** in the game, and this facilitates the memorization of their decisions (National Research Council 2000). Games can therefore be used to facilitate learning certain skills, for which traditional teaching methods are not satisfactory (Mayo 2007).

What Games for Teaching?

These past years, many digital Learning Games have been developed. **Digital Learning Games** do not require any physical material and offer

many advantages such as adapting to the learner's profile, allowing access to the game anytime and anywhere, and displaying infinite patience when it comes to repeating concepts. In addition, the new generation of students is accustomed to playing computer games. An American study carried out in 2000 showed that, on average, students who have obtained an undergraduate degree spent only 5000 h reading compared to 10,000 h playing video games and 20,000 h watching television (Prensky 2001). With the democratization of smartphones and tablets over the last 20 years, this tendency has no doubt been amplified. In 2015, 75% of Americans between 13 and 17 had access to smartphones, and more than half had access to tablets (Lenhart 2015). In this context, it is in our interest to provide tools and methods to help teachers use the attractiveness of video games to facilitate the acquisition of complex skills.

In order to be effective, Learning Games need to offer engaging game mechanics that serve the educational objectives. There are many theories on the best way to choose and integrate these game mechanics with the learning content. The **extrinsic motivation approach**, for example, was very common during the 1980s and 1990s, when Learning Games were referred to as "edutainment." With this approach, inspired by the behaviorist learning theories, gaming and learning are treated as separate entities. Indeed, the learners are usually first asked to perform certain educational exercises, and, if they succeed, they are given access to a short game or receive points and badges as a reward. This approach met much criticism and was often regarded as "sugar coating" over drill and practice exercises (Bruckman 1999). Nevertheless, this approach has become quite popular in higher education these last years under the term "gamification." Indeed, it is easy to gamify existing courses on online platforms used by universities and MOOCs (massive open online courses) (Gené et al. 2014). Many of these platforms offer plugins to create badges, progress bars, and leaderboards, and they show fun content only if the learners have achieved a certain goal (a certain number of points or activities, etc.). In regard to the limitations of this approach, several Learning Game designers

have chosen to explore another direction called **intrinsic motivation approach** (Fabricatore 2000; Kafai et al. 1998), influenced by the constructivist learning theories. It consists in blending game mechanics with the learning content instead of using them separately. The idea is to choose a game design that is adapted to the educational goal and weave it into the pedagogical activities. According to numerous studies (Habgood 2007; Lepper and Malone 1987; Ryan and Deci 2000), it is this cohesion between learning and fun that truly engages the students in their activity and facilitates the learning process. However, this approach implies creating custom Learning Games in collaboration with teachers and game designers, a very costly process that is not always possible. By combining both approaches, maximum efficiency can be obtained.

It is important to understand that the effectiveness of a Learning Game depends not only on the characteristics of the Learning Game artifact but also on the way it is used (Sanchez et al. 2017). Therefore, the game mechanics and the educational content do not necessarily need to be embedded in the Learning Game artifact itself. For example, teachers can use basic exercises in a fun context by distributing rewards, setting up battles between groups, or introducing the concept with a story. The other extreme is also possible, using a pure game, such as *Assassin's Creed* (Assassin's Creed Ubisoft, <https://assassinscreed.ubisoft.com/>), for educational purposes (teaching history (<https://www.youtube.com/watch?v=TAeut18BHOA>)).

Resistance to Learning Games

The use of Learning Games in the context of higher education is subject to many forms of resistance. First of all, the use of games with adult or young adults can be problematic because they often view games as futile and only fit for children (Eyster 2008). This opinion is sometimes shared by colleagues and superiors. Teachers who use Learning Games therefore need to prepare a flawless argumentation that shows how their Learning Games will help students reach the given educational goals.

Another critical concern is the student's evaluation: is it fair to evaluate learners according to

their scores and actions in the Learning Game? The nature of games, as defined by Caillois (1961), implies that playing can only be done free willingly and the actions taken in the game should not have any consequences on the real world. Using a Learning Game to grade students therefore contradicts the very notion of play.

Finally, it is unrealistic to believe that one Learning Game will suit all students. We all have different player profiles (Seeker, Survivor, Daredevil, Mastermind, Conqueror, Socializer, and Achiever) (BrainHex questionnaire, <http://survey.ihobo.com/BrainHex/>) and therefore do not necessarily like the same types of games (Nacke et al. 2014). This must be kept in mind when designing Learning Games: it is best to choose game mechanics that cover several player profiles.

Even though the use of Learning Games faces resistance in higher education and requires complex multidisciplinary design skills, many have proven their efficiency in various domains. In the next section, the advantages that games can offer for higher education will be presented and illustrated with examples of games presently used

in universities, graduate schools, and professional training programs.

Advantages of Games for Higher Education

An Opportunity to Simulate and Manipulate

Computer games have the advantage of offering adaptable virtual environments that are very useful for recreating specific situations and simulating the context in which learners will use their skills. This is particularly advantageous when the context is impossible or very difficult to reproduce because of its costly or dangerous nature. For example, *The Resuscitation Game* (The Resuscitation Game (imaginary), <https://www.youtube.com/watch?v=0aDzjJTWUsc&feature=youtu.be>) is used to teach medical procedures and reanimation technics for neonatal resuscitation. *Rail Simulator* (Rail Simulator (electronic Arts), <https://www.origin.com/fra/en-us/store/rail-simulator/rail-simulator>) (Fig. 1) allows future train drivers to validate their management and driving skills. Virtual reality is one of the latest advances in simulations. This

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Games in Higher Education, Fig. 1 Train simulator (*Electronic Arts*) used for training train drivers. (Source: <https://www.origin.com>)

technology immerses the learners in an interactive virtual world and allows them to practice their orientation and manipulation skills. Virtual reality is also used for simulating stressful situations in order to help learners control their emotions (Marfisi-Schottman et al. 2018; Ponder et al. 2003).

Enhanced Emotional Engagement

Learning Games have the power of involving students in their own learning process with game mechanics such as competition, rewards, social recognition – and many more – that enhance motivation and activate the students' capacities (Dondlinger 2007). Learning Games offer much more than a simple simulation environment. They offer the possibility of creating role-playing games based on complex scenarios with stories and quests. Thanks to these mechanics, learners can project themselves into a character and are emotionally engaged in the action of helping this character attain his/her goal. Throughout the game, the character will need to master various

skills to fulfill his/her objectives. Many educational games offer such engaging scenarios. *Starbank The Game* (<http://serious.gameclassification.com/EN/games/14090-Starbank/index.html>) (Fig. 2), for example, is used to train new bank employees; *Les aventures de Casey Warren* (<http://blog.seriousgame.be/les-aventures-de-casey-warren>) is used to train employees in data security.

Relief from Routine

Using games is a good way to break the routine that sets in after several months of class. Introducing this teaching method changes the usual dynamics of the class and gives a second chance to the students who feel they are too far behind or that have given up all interest in the class. The games also require a set of new skills (communication, organization, tactical planning) that are not usually put forward in class. This provides teachers with fresh insights into their students as learners (Kirriemuir and Mcfarlane 2004). Games also create a break, a state of “relaxed attention” that



Games in Higher Education, Fig. 2 Starbank The Game (BNP Paribas), used to train bank employees. (Source: <http://serious.gameclassification.com>)



Games in Higher Education, Fig. 3 CheckiO used for teaching computer programming. (Source: <https://checkio.org/>)

enhances learning (Thiagarajan and Thiagarajan 2003). *CheckiO* (<https://checkio.org/>) (Fig. 3), for example, offers a new approach for learning Python and JavaScript programming languages.

A New Student-Teacher Relationship

Games can also be designed to help teachers. It is possible to integrate certain repetitive tasks into the games such as the explanation of certain concepts or corrections. This gives the teacher more time to interact with the students, to advise them, and to help those in need. The student-teacher relationship is therefore redefined.

In addition, when it comes to training adults, who already have professional experience, games can turn out to be better suited than traditional training (Federation of American Scientist 2006; Mayo 2007). This can be explained by the fact that adults find it difficult to “go back to school” and accept criticism from a teacher, who is often younger than them. Learning Games offer an original, less academic way of learning. In addition, the

games can be designed so that all forms of judgment come from the game and not the teacher. In *Laboratorium of Epidemiology* (<http://loe.ujf-grenoble.fr/content/story>) (Fig. 4), the hospital’s chief doctor asks the students to write an essay. These essays are actually corrected by the teacher, but the fact that the comments are delivered by the chief doctor gives them more weight and eliminates remonstration (Ney and Balacheff 2008).

A Means to Evaluate, Track, and Provide Feedback

Finally, Learning Games offer the technical means to track the student’s actions and automatically evaluate certain skills, a feature which is very important in higher education and professional training (Carron et al. 2008). These tracks can also be analyzed in real time and presented on a monitoring platform for teachers and students themselves. Finally, these tracks can also be used to automatically adapt activities according to the learner’s level in order to keep him or her in a state

of constant motivation (Oostendorp et al. 2014). For example, the *V3S* Virtual Reality training platform offers dynamic situated feedback and progressive learning scenarios by adapting the complexity of the situations to the learner's activity and level (Barot et al. 2013). The *Reviattech* simulators (Fig. 5) also analyzes the usage tracks to provide personal feedback on technical and nontechnical skills (Huguet et al. 2016).



Games in Higher Education, Fig. 4 Laboratorium of epidemiology. (Source: <http://loe.ujf-grenoble.fr>)

Current Research Questions

Learning Games have much to offer for higher education. However, there remain a number of important issues that need to be addressed before university teachers and professional trainers willingly adopt them. In this section, some of the current limitations and major research questions related to the specificities of Learning Games in higher education will be identified. First of all, research on methods to facilitate the design of custom Learning Games for specific higher education skills will be discussed. Then, the latest research on how to help university teachers resist the skepticism of their students and colleagues when they want to use games in their classes will be presented.

Methods and Tools to Create Custom Learning Games

Specialized websites offer access to Learning Games libraries (Serious Game Classification, <http://seriousgameclassification.com>, GooseChase EDU platform, <https://www.goosechase.com/edu/game-library/>, S'cape <http://www.scape.enepe.fr/>). They allow teachers to both find existing Learning Games, they can integrate into their courses, and to share their own Learning Games. These libraries are quite successful with middle school teachers because there is a large body of teachers that are interested in the same learning content and therefore have the same educational needs. In higher education, however, the curriculum is not as precise, and



Games in Higher Education, Fig. 5 Reviattech simulator for learning technical procedures and social skills. (Source: <https://reviatech.com>)

teachers create their own pedagogical activities. In this context, it is very difficult to find Learning Games that fit all their requirements.

In order to help teachers create their own custom Learning Games, several researchers have proposed methods and tools such as *ScenLRPG* (Mariais et al. 2012), *Player-VG* (Padilla Zea et al. 2011), and *LEGADEE* (Marfisi-Schottman et al. 2010) to help them communicate and collaborate with game experts.

Although working with game designers is ideal, it is often too costly and complicated to organize. Teachers can therefore use Learning Game authoring tools, which allow them to create digital games on their own, without any computer programming skills. Here are a few examples of authoring tools for specific Learning Game types: *eAdventure* for creating simple point and click games (Moreno-Ger et al. 2008), *Storytec* (Mehm et al. 2010) for puzzle games, and *JEM iNVENTOR* (Karoui et al. 2017) for educational mobile treasure hunts. These editors allow teachers to become independent and capable of improving their Learning Games year after year, adapting them to the new curriculum or a modification in the student profile.

An interesting approach, also called **game modding**, consists in asking players to create new levels for existing games. This movement appeared in the gaming industry with the famous *Counter-Strike*, a “mod” of the game *Half-Life*, designed by two players (Kücklich 2005). This concept provides several advantages for Learning Games (El-Nasr and Smith 2006). The first advantage is that students are much more likely to create the type of game that they like when following the latest trends (escape games and choose-your-own-adventure-type games). The second is the fact that the students will need to acquire a deep understanding of the knowledge and competencies that should be integrated into the Learning Game. Thirdly, teachers then have a large selection of Learning Games to choose from or build on for their future classes.

These methods and authoring environments have certainly facilitated the creation of custom Learning Games, but the process remains very complex and time-consuming for results that are not always satisfactory. Even though the authoring

tools allow teachers (or students) to create their own Learning Games, it is very difficult for them to imagine a gameplay that is fun and that also serves their pedagogical objectives. They might therefore use game mechanics that are not at all adapted to their educational goals. For example, the latest trend is to create educational escape games, even though its core game mechanics (time pressure, mini-puzzles, stress) does not create the right conditions for learning. This type of game, however, is a well-adapted alternative to a quiz in order to verify if the students have understood targeted concepts. The know-how required to select the best game mechanics and create a pedagogically effective Learning Game remains difficult to pinpoint, even for experienced Learning Game designers.

Help Teacher Convince Game Skeptics

The negative perception of games in higher education is an important issue. While some university teachers have never been more enthusiastic about Learning Games, the majority remain very skeptical or even openly opposed to such teaching methods, which they see as a waste of time. In this context, it is very difficult for teachers to try using Learning Games, if they are not 100% convinced it is going to work. This implies knowing about game mechanics, the way they can be used to attain educational goals, and having several successful examples of Learning Games in mind.

Half a dozen MOOCs on Learning Games and gamification have recently been put online to help teachers acquire such knowledge. For example, MIT offers a MOOC entitled “Design and Development of Games for Learning” (<https://www.mooc-list.com/course/design-and-development-games-learning-edx>), the University of Rotterdam offers a MOOC on Serious Gaming (<https://www.coursera.org/learn/serious-gaming>), and the University of Pennsylvania offers a MOOC on gamification (<https://www.coursera.org/learn/gamification>). Le Mans University (<https://lium.univ-lemans.fr/en/ludifikaction/>), in France, also offers a course to help teachers create their own Learning Games with the help of pedagogical engineers.

The student’s skepticism toward games can be changed if the teachers clearly explain the educational objectives of the Learning Games and why

they have chosen to use a game instead of a classical teaching method. There is a difference between mastering the rules of a game and understanding the educational concepts embedded in it. This is why a phase of reflection and debriefing is necessary after the Learning Game (Garris et al. 2002). This debriefing serves several purposes such as clarifying the educational purpose of the Learning Game (Aldrich 2005), fostering meta-cognition (Lederman 1992), and facilitating knowledge transfers to other domains and real situations.

Some teachers push the concept even further by asking their students to write an “astonishment report” on their experience playing the game and the skills they acquired. This concept is inspired by management methods (Vigier and Bryant 2009). The evaluation of the students is based on the quality of their essay and not on their actions in the Learning Game. This evaluation method seems effective as it allows the students to learn, without being penalized by errors made in the game, and encourages post analysis and self-reflection on the learning outcome.

Educating teachers about game mechanics and how they can be used for teaching and encouraging them to brief/debrief their students are both good ways to help teachers convince Learning Game skeptics among their students and colleagues. However, the best way to convince these skeptics is to provide hard proof that Learning Games enhance learning. The question of evaluation is extremely complicated and has yet to be dealt with. The usual pre- and post-knowledge tests, carried out with a control group, that does not play the Learning Game, contain too many variables and can easily be flawed.

Cross-References

► Augmented Reality and Its Use in Education

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Games, Simulations, Immersive Environments, and Emerging Technologies

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Synonyms

Advanced computer human interactions; Game-based learning; Serious game; Virtual and mixed reality

Introduction

This entry presents an overview of advanced technologies to support teaching and learning. The use of innovative interactive systems for education has never been higher. Far from being just a trend, the objective is to use the current technology to cover educational needs and create relevant pedagogical situations. The arguments in their favor are generally their positive effects on learners' motivation and the necessity to provide learning methods adapted to our growing digital culture. The new learning technologies and emerging trends are first reviewed hereunder. We

thus define and discuss learning games, gamification, simulation, immersive environments, and other emerging technologies. Then, the current limits and remaining scientific challenges are highlighted.

Learning Games

The use of games in education is not a novelty. Humans have always used games to teach young people. However, for children growing up, education becomes less and less fun. The Serious Game approach changes this trend by arguing that the game remains a pedagogical means that can be useful at any age.

The term Serious Game can be used to cover a wide variety of systems. In its broadest definition, Serious Games are games used for purposes other than mere entertainment (Susi et al. 2007). The serious intention can be educational, informational, commercial, or ideological, for instance. When the main goal is to favor knowledge learning or competencies building, the term used is Learning Game. These games can be computer supported or not. Thus, Learning Games can be played using cards and other materials (board games) or using computers, tablets, or smartphones (digital games).

The main benefit of game-based learning is the user's motivation linked to the inherent goals of the game whose fulfillment is a source of satisfaction and rewards. So the game goals motivate the player's actions. Moreover, above all, a game has the specificity of being different from the real world, and players being able to act without fearing the consequences of their actions. Users can try and immediately see the impact of choices. According to the feedback, players can learn and develop abilities. The main educational approach is therefore active learning; the game allows the learner to decide and act within a set of game rules. For example, in the Learning Game *Refraction*, learners have to split a laser into several beams in order to redirect fractions of the original full-strength laser to power spaceships (Fig. 1).

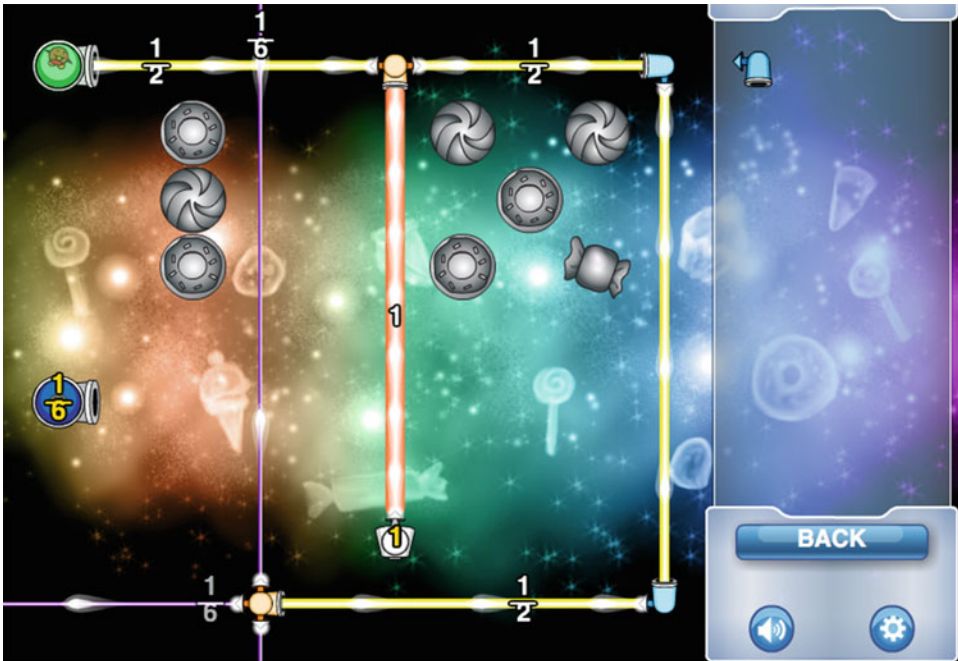
This puzzle game helps students to learn and apply the concepts of basic fraction manipulation in mathematics.

With games, learning occurs through interactions with objects, places, and other people (collaborative learning). Finally, emotion is another important pedagogical factor. The universe and the narration of the game contribute to engage learners by making them feel emotions. Game-based learning is definitely a powerful means to take into account the game and digital culture of the new generation of learners, characterized by a relatively short attention span and a preference for exploration and discovery.

The educational purpose of a Learning Game can also be achieved through a debriefing. Often conducted with a teacher, debriefing sessions allow to get out of the game and facilitate the transfer of skills to other situations. The role of the teacher is also considered to be important to animate the game situations and to monitor the learners.

Actually, a wide variety of learning games can be found. For instance, location-based games are played on mobile devices and are useful to promote situated learning. Educational Alternate Reality Games (ARG) are based on transmedia storytelling to propose a social experience to learners who need to collaborate to accomplish activities and solve problems. In this kind of games, learners are asked to coordinate real-life activities (finding objects, talking to characters, etc.) and online activities (watching video, responding to emails, etc.). As another example, Epistemic Games make it possible for learners to learn to think in innovative ways by playing the role of professionals while learning knowledge and abilities they apply in the game (Shaffer 2006).

Nevertheless, most educators and teachers have not been trained in the pedagogy of gaming. The use of games in the classroom implies a new paradigm for the student-teacher relationship and raises many technological questions that most teachers are not ready to face. In any case, the support of school technical staff is crucial for the installation and running of the games.



Games, Simulations, Immersive Environments, and Emerging Technologies, Fig. 1 Refraction: a puzzle game to learn fractions. (Source: centerforgamescience.org)

From the point of view of the creation of learning games, inevitable technical issues are raised. The development of the game must ensure that the proposed interactions are in line with teaching expectations. So teachers need to be part of the design team. Another approach exists with the provision of authoring tools that allow teachers to create learning game without coding. This possibility is detailed later in the part dealing with research questions.

Gamification

Turning a learning environment into a serious game requires a complete redesign, which is very expensive and time consuming. An easier solution is to gamify a course by adding game design elements. In a general way, gamification consists in using game components in non-game contexts. This approach is used in various domains such as marketing, health, architecture,

and crowdsourcing. In education, gamification relies on game design features embedded in a learning situation to foster student motivation (Deterding et al. 2011). The most common game elements are: points, badges (trophies symbolizing a task fulfillment), leaderboards, object collection, etc. A good example of gamification is *Classcraft*, a platform to gamify classrooms (Fig. 2). With *Classcraft*, teachers and students play together in the classroom a role-playing game. Students can level up, work in teams, and earn powers that have real-world consequences (e. g., switch seats, choose the order during presentations, etc.).

The Learning Management Systems (LMS) propose more and more often gamification features. For instance, some plug-ins can be integrated to Moodle to gamify courses: badges, achievements, points, etc. Some other platforms even build gamification into the bones of their learning solutions (i.e., The Academy LMS, Paradiso LMS, etc.). In any case, these systems require



Games, Simulations, Immersive Environments, and Emerging Technologies, Fig. 2 Classcraft, a platform to gamify classroom activities. (Source: classcraft.com)

time from the teachers to set up the game features they want to set up for their students.

Simulation

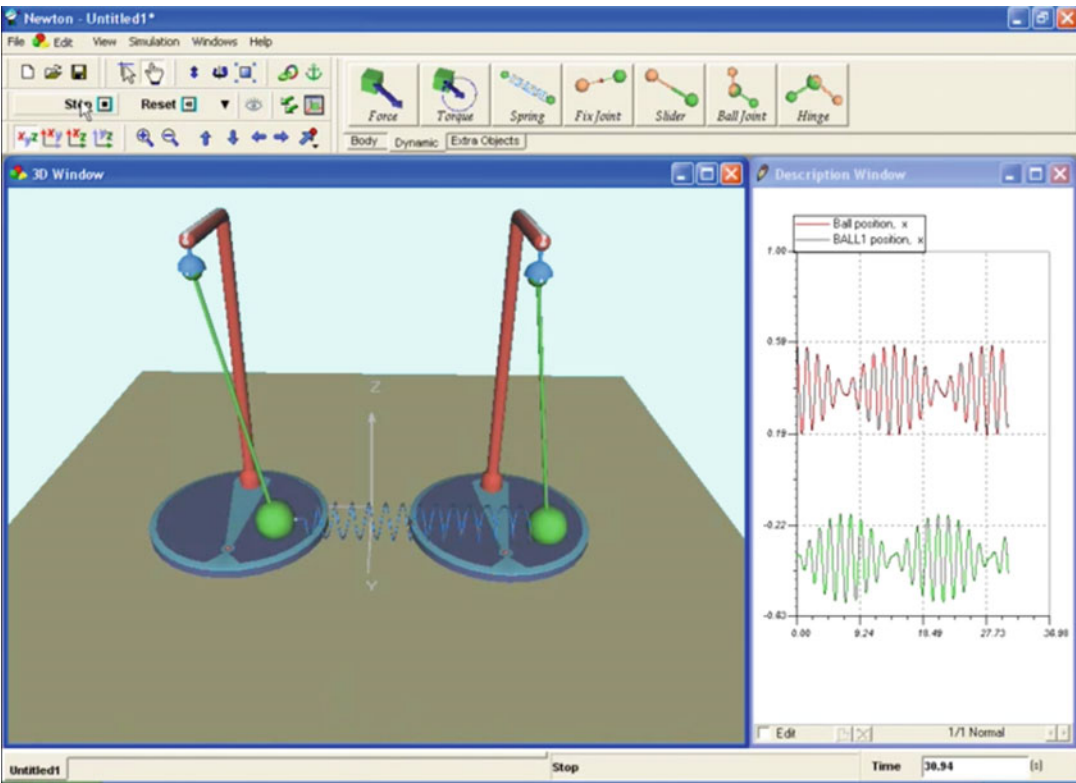
Simulations should be distinguished from Serious Games. A game can be based on a simulator, but this is not necessarily the case. Digital simulations are based on virtual environments that replicate, with a high degree of fidelity, real-life phenomena, or situations. For instance, simulators in STEM fields (science, technology, engineering, and mathematics) rely on specific models and equations (electronics, physics, etc.) to calculate results with a given set of input data. A simulator gives the opportunity to carry out experiments by modifying inputs and observing the outputs generated by the system. For example, with *Newton*, users can manipulate 3D virtual objects and investigate real-life physics experiments interactively (Fig. 3).

Even if simulations cannot replace practical learning with real devices, they offer the possibility to train without costly materials and avoiding potential dangers. Simulators can also be used in non-STEM fields to represent a global behavior or

situation. For example, simulators exist to train people to apply procedures or to use the right sales method in front of customers.

As said before, some Serious Games integrate a simulator, i.e., a model of a real-world phenomenon (in mechanics, physics, economics, etc.). For instance, *Physica* is an example of serious game based on a physical simulator. In this case of simulation-based serious game, a scenario is designed according to pedagogical objectives to be achieved. Another example is *Pulse!!*; a simulation-based learning game for health care professionals which allows them to train and practice without the risk of harming patients (Fig. 4). Learners work in a virtual hospital where they respond to emergency situations, diagnose, and treat patients as they would in the real world. The game adds a narration to the simulator and sets goals or actions to be achieved.

Nevertheless, the situation does not necessarily need to be realistic in a serious game: metaphorical situations can also lead learners to build skills. For instance, a fiction science scenario can help to learn concepts in sustainable energy. The skills developed can be meaningful for learners even in an imaginary situation, far from reality. There is no need to have a model to reproduce situations



Games, Simulations, Immersive Environments, and Emerging Technologies, Fig. 3 Newton: a simulation environment to manipulate and investigate real-life 3D physics experiments interactively. (Source: newtonlab.com)



Games, Simulations, Immersive Environments, and Emerging Technologies, Fig. 4 Pulse!! a simulation-based learning game for health care professionals. (Source: breakawaygames.com)

realistically; the game can be based on a pre-defined scenario.

Immersive Environments

Virtual Reality (VR) is a computer technology that uses devices and three-dimensional interfaces to simulate the user's physical presence with realistic images, sounds, and other sensations. The key elements in experiencing virtual reality are a virtual world, immersion, sensory feedback (responding to user input), and interactivity (Sherman and Craig 2002). Interactivity not only refers to the user interacting with the system but also to multiple users interacting together and collaborating within the same virtual space.

Several devices can be used in VR. Head mounted display (HMD), goggles with a screen in front of the eyes, are the most popular solution, and less and less expensive. More sophisticated VR systems exist, for instance, CAVE (Cave Automatic Virtual Environment) are immersive virtual reality environments where projectors

display multiple images on the walls/floor/ceiling of a small room (Cruz-Neira et al. 1992). For the manipulation in these virtual environments, the possible devices range from simple joystick to specific data gloves or haptic feedback systems.

Compared to traditional Technology-Enhanced Learning (TEL) systems, VR environments make it possible to include the body in the learning process, and more generally to integrate sensorimotor and proprioceptive aspects, thanks to rich interaction modalities. It is thus possible to implement learning methods that immerse the learner into a given context. For example, immersive virtual environments are used for adult lifelong training in complex domains where technical systems are difficult to apprehend and human factors are critical. In I3TE (Immersive 3D Training Environment, Eon Reality), plant operators and engineers have the opportunity to train together in the same environment by reacting to a wide range of situations (Fig. 5).

By definition, virtual reality applications are often based on a simulation. Immersion of the learner can greatly facilitate situational learning.



Games, Simulations, Immersive Environments, and Emerging Technologies, Fig. 5 Training of operators in a CAVE (iCube) with the environment I3TE. (Source: eonreality.com)

Nevertheless, the fact of using virtual reality is not enough to ensure learning, just as visual fidelity is not a guarantee of pedagogical effectiveness (Bossard et al. 2008). A reflection must be made both on the didactic situations and on the scenario. Again, gaming scenarios can be used to motivate the player to improve skills. As discussed further, research questions remain in this field.

Emerging Technologies

In last years, devices and sensor technology evolved considerably, while costs of hardware and development platforms decreased quickly. Augmented and Mixed Reality technologies bring new opportunities for education and training. Augmented Reality (AR) overlays the real world with virtual content to create an immersive environment placing the learner in real-world context and engaging all senses (Bacca et al. 2014). More generally, Mixed Reality (MR) was defined as a continuum between real world and virtual world (Milgram and Kishino 1994). The objective is to enrich a situation based on the real world or add realism in a virtual environment. This objective can be achieved using many devices such as screens, cameras, see-through glasses, mobile devices, and tactile or tangible interfaces. Some research on the integration of mixed reality interactions into educational applications have highlighted their potential, mainly to improve the anchoring of learning and positioning learners in authentic situations (Egenfeldt-Nielsen 2006).

For example, the *wekit project* aims at experimenting new forms of interaction for professional training (Fig. 6). The idea consists in capturing expert experience and sharing it with trainees during task-sensitive augmented reality. A pilot study is currently conducted in the field of aircraft maintenance in order to present data in context and augment performance (Guest et al. 2017).

Tangible User Interfaces (TUI) can also be used for advanced interactions in educational activities. With TUI, users can interact with a digital environment through physical objects. For instance, TUI can be coupled with interactive tables, taking advantage of the user ability to manipulate physical objects. Another recent trend concerns learning games that mix real objects (cards, game pawns) and virtual environments (game board on tablets or smart phones).

Using principles derived from embodied cognition, TUI can increase learning performance by offering sensory perception and feedback (Skulmowski et al. 2016). Thus, the relationship with objects is not only physical but has also a cognitive dimension. It impacts the way users perceive the environment. The importance of movement and manipulation has often been demonstrated in children education.

Current Limits and Research Questions

In all types of learning environments described above, important research questions remain.

Games, Simulations, Immersive Environments, and Emerging Technologies,
Fig. 6 Aircraft maintenance training with the use of AR technology in the *wekit project*. (Source: wekit.eu)



Some scientific locks are common; others are more specific to a category of systems. Overall, the main problems concern the cost of designing and building these environments because of their complexity and the high level of interactivity they offer. Budgets can very often be substantial, from several tens of thousands of dollars to several million for some applications (for example, Pulse!! has cost ten million dollars).

Beyond budgetary constraints, the aforementioned systems generally target a relatively small audience by addressing the development of specific knowledge or skills. It is therefore not easy to have a “return on investment” and their creation is therefore risky. In order to avoid risk-taking and reduce costs, it is desirable to be able to reuse some elements: scenarios, components, resources, game engines, simulation engines, interaction techniques, etc. Unfortunately, this capitalization has so far been poorly supported. The main obstacles are related to interoperability difficulties, whether technical (software engineering issues) or semantic (educational science issues).

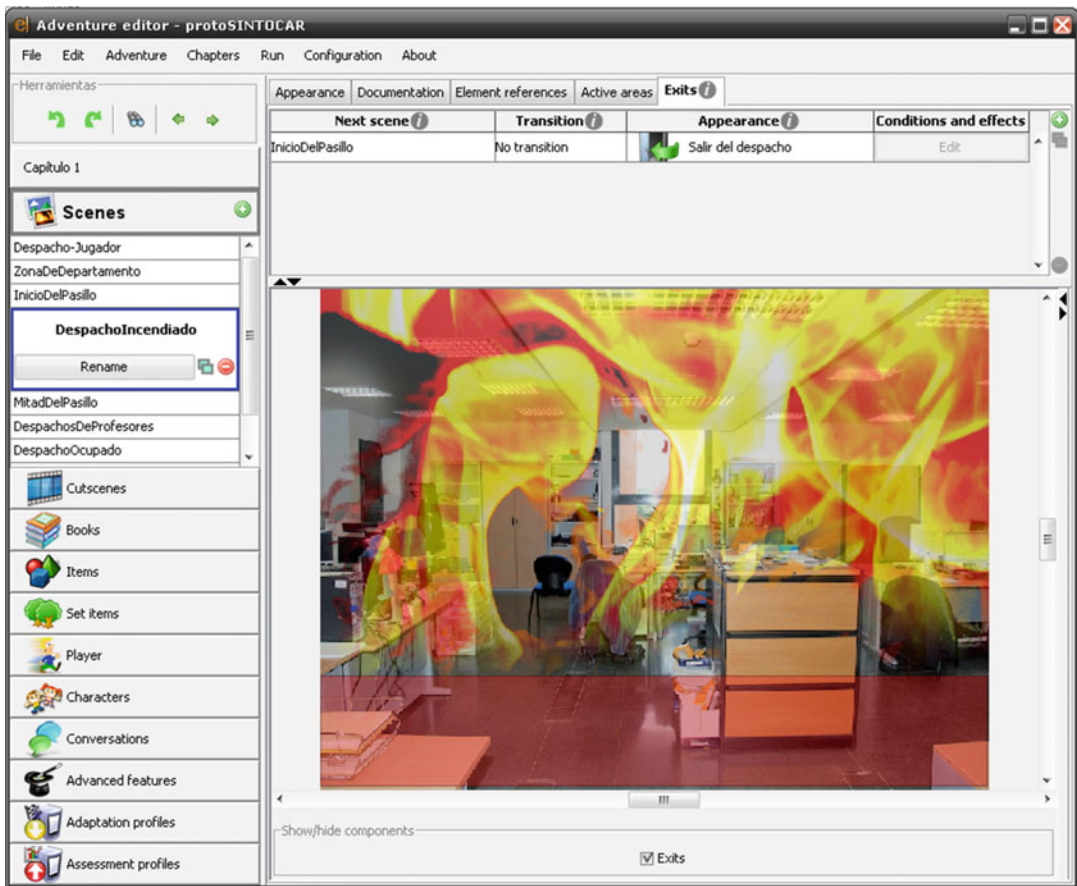
In order to meet this need for capitalization and also to involve teachers and subject matter experts in the process of designing learning environments, research works have been conducted for several years to propose authoring tools (Murray et al. 2003). The main purpose of an authoring tool is to enable people without any programming skills to design and deliver instrumented learning activities. An authoring tool in education is thus used to create educational environments, ranging from simple resources (content, exercises, etc.) to more complex systems (serious games, simulation, etc.). In the latter case, authoring tools mainly focus on specific situations, such as *e-Adventure* (Torrente et al. 2010) to design point and click adventure games (Fig. 7), *JEM iNVENTOR* (Karoui et al. 2017) to create mobile learning games, or *SimQuest* (www.simquest.nl) to configure physics simulations. The difficulty of these research works is not only technical but also concerns the support of pedagogical design. It is therefore essential that authoring tools guide teachers by providing them design methodologies

related to the kind of interactive learning environment they want to use with their students. The major challenge lies in providing an authoring tool that is, for a teacher, simple enough to quickly create interactive activities and rich enough to set up situations adapted to a particular learning subject and audience.

A research topic to be developed concerns the interoperability between authoring tools. Since they are often specific to the design of specific resources or activities, it would be useful to combine them to propose richer learning situations. For instance, we have seen before that a simulation environment can integrate both real and virtual objects, used in conjunction with a game scenario. The complexity of this type of environment can difficultly be managed without connecting existing authoring tools.

Another research question is related to the use of computer traces that can be collected in interactive learning systems. In these computerized environments, it is possible to gather data on the actions carried out by each learner. Advanced interaction devices also make it possible to have information from sensors (positions, gestures, etc.). Data analysis or learning analytics techniques can then be applied to provide semantic information from these raw data. Several uses of these traces are then possible:

- To automatically adapt activities, for instance, in the case of learning games, the challenge is to be able to adapt the level of difficulty according to the learners’ skills in order to keep them in a state of motivating flow (van Oostendorp et al. 2014).
- To give feedback to students, the objective being to help them to evaluate their actions and encourage reflexivity. The aim is also to make the learners step back from the situation and thus encourage the transfer of learning to other contexts. On these issues, artificial intelligence can lead to major advances. For example, chatbots are already being used for educational tutoring or individual didactic support (Soliman and Guetl 2013).



Games, Simulations, Immersive Environments, and Emerging Technologies, Fig. 7 e-Aventure, an editor to create serious adventure games. (Source: e-adventure.e-ucm.es)

- To provide pedagogical indicators in order to enable the teacher to monitor the game and immersive activities (individual and collective). In such settings, educational monitoring and intervention are not easy; the teacher may lack information about the tasks performed by learners. So, the teacher activity support must be a concern before, during and after the instrumented learning activity. On this topic, interesting research concerns technologies to support the teacher in the orchestration of learning activities. For instance, tangible interfaces can be used for the real-time management of events and activities in a classroom (Dillenbourg and Jermann 2010).
- To inform the designers, or the design team, of the interactive learning activities to help them to redesign educational scenarios and tasks (re-engineering approach).
- To provide researchers with data for the scientific evaluation of the systems (impact on learning, motivation, usability, etc.).

In connection with this last point and to conclude, it would be important in the future to develop studies showing what kind of activities and what kind of computer support or Human-Computer Interactions should be implemented to promote certain types of learning. Of course, in this area it is important to keep some design

freedom, but recommendations, best practices, and reproducible methods could helpfully guide teachers and instructional designers.

Cross-References

- [Digital Simulations in Healthcare Education](#)
- [Game-Based Learning](#)
- [Gamification](#)
- [Mobile Computing and Mobile Learning](#)
- [Technological Innovation in ICT for Education](#)

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Gamification

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Synonyms

[Edutainment](#); [Ludicization](#)

Gamification: A Definition

Coined in 2008, the term gamification has not yet reached a consensus from the academic community, and, depending on the considered authors, two categories of definitions are proposed. A first category of definitions is based on the etymology of the term. Gamification consists of “making or fabricating a game,” i.e., applying game mechanics and using game elements such as badges, points, bonuses, and leaderboard in order to convert a nongame context into a game-like activity. This definition is based on a point of view about what is a game that falls within “essentialism,” i.e., the functions of a game result from a set of attributes. A second category of definitions is currently emerging. This category of definitions considers gamification to be a process focused on the player experience. This process consists of the implementation of motivational affordances grounded in game design principles and aiming at fostering “gamefulness” or “gameful experience.” These latter definitions insist on the subjective nature of the experienced value of a game. Play is considered to be based on activity and meaning originating from the player. Gamification results in (internal) psychological and (external) behavioral outcomes because the focus is on influencing learning performances, attitude, and/or behavior. From a learning perspective, gamification is considered to provide positive effects by fostering the learner engagement into epistemic activities. However, potential negative outcomes, such as increased competition, are also reported.

Introduction

The term gamification (coined as “game-ification”) appeared in 2008 in the digital media economic sector (Deterding et al. 2011a). In a blog post following the Social Gaming Summit, Bret Terrill (2008) describes the word as “taking game mechanics and applying to other web properties to increase engagement.” Since then,

the term has been popularized in different conferences (Google Tech Talk) by Zimmermann in 2010 and Amy Jo Kim in 2011 (Kapp 2012). Gamification, as an emerging concept, has also attracted considerable attention of the educational research community, and gamification is becoming a popular subject for academic inquiry (Hamari et al. 2014). Besides that, gamification is often incorporated in persuasive technologies to influence attitude and behavior.

Etymologically, the word gamification is based on the Latin verb *facere* (“to make” or “to fabricate”), reflecting the idea that it is possible to “create a game.” The concept emerged in the digital media economic sector (Deterding et al. 2011a) but was early adopted by educators. The concept has close relationships with edutainment and game-based learning. However, edutainment is used in a broader sense and is not limited to game principles. Indeed, edutainment also refers to media for leisure such as television. Gamification is generally considered differing from game-based learning as gamification is more about applying game design principles to nongame contexts than using individual video games.

In a usual gamification process, gameplay elements are implemented in real-world processes or activities to stimulate behavior (Deterding et al. 2011a). For example, Classcraft (see the example below) consists of implementing loss or gain of points, powers, and privilege as well as random events for classroom management.

Recent definitions, characteristics, and perspectives about gamification (Lieberoth 2015) and the implemented motivational affordances are discussed in section “[Gamification: Definitions and Characteristics](#).” The resulting psychological and behavioral outcomes mentioned in the related literature are discussed in section “[Gamification and Learning, Attitude and Behavior Changes](#).” Section “[Examples](#)” provides some examples of gamified contexts in secondary and higher education, and regular households. Section “[Criticisms Leveled](#)” is dedicated to stress the ongoing debates on gamification and its use for educational

purposes. Current trends in the gamification field are highlighted in section “[Current Trends in the Gamification Field](#).”

Gamification: Definitions and Characteristics

The emerging scientific literature describes gamification firstly as game mechanical elements and secondly in psychological terms. According to the first perspective, Terrill (2008) describes gamification as “taking game mechanics and applying to other web properties to increase engagement.” Since then, several definitions have been suggested, such as “the use of game design elements in non-game contexts” (Deterding et al. 2011a) and “using game-based mechanics, aesthetics, and game thinking to engage people, motivate action, promote learning, and solve problems” (Kapp 2012, p. 1). Game elements (or game design elements) are the game components or the objects that the player interacts with. Some game elements enable rewarding the player (points, badges, bonuses, leaderboard, etc.), while others are linked to the gameplay (limited time, game levels, etc.). Game mechanics are methods invoked by agents for interacting with the game state (Lieberoth 2015) such as the use of a dice as randomizer, movement of playing tokens, or acting out roles. Game mechanics create emergent gameplay. Game mechanics are diverse and fall into several categories that are used to categorizing games (Seaborn and Fels 2015).

However, basing definitions of gamification on a set of game elements or game mechanics is problematic. There do not seem to be a basic set of elements that are unique to games, and game mechanics might be not specific to games (Huotari et Hamari 2017). As a result, according to a second perspective, gamification is considered to be a process focused on the player experience. In that case, gamification is grounded on two core concepts: motivational affordance and gamefulness. Motivational affordances refer to actionable properties between an object and an actor (Gibson 1977). The user is not forced to act upon these

objects, but they demand interpretation by the actor. Characteristically, they open the possibility for the occurrence of motivational needs and emotional states. Thus, rather than focusing on game elements that the user has automatically to interact with, gamification is considered to resulting from voluntary player’s interactions with the game. Play is considered to be based on activity originating from the player (Sanchez and Mandran 2017). The term “gamefulness” or the expression “gameful experience” is used in this context to describe an experiential condition that is unique to games. This experiential condition makes possible for anyone to recognize a game. Play is considered to be based on activity and meaning originating from the player. Therefore, *gamification* can be defined to be *the implementation, in nongame contexts, of motivational affordances grounded in game design principles and aiming at changing the meaning of the situation and fostering gamefulness where the focus is on influencing learning performances, attitude, and/or behavior*.

A way out of the contrast we signaled is to assume that gamification presupposes the first as well as the second perspective mentioned which is more or less the case in the definition of Seaborn and Fels (2015): *gamification is the intentional use of game elements for a gameful experience of non-game tasks and contexts* (p. 17). Game elements are, for this definition, patterns, objects, principles, models, and methods directly inspired by games.

Gamification and Learning: Attitude and Behavior Changes

In recent years, a number of studies have been conducted on the effects of gamification on learning processes through integration of several game elements (e.g., badges, leaderboards, points) in the learning environment (Caponetto et al. 2014, Dichev and Dicheva 2017). Most studies conducted in the education area on the effect of gamification focus on two variables: learning performances and learners’ motivation.

Regarding learners' performance, most studies show a positive impact of gamification as the integration of one or several game elements. De Marcos et al. (2016) compared educational game, social networking, gamification, and social gamification approaches in their impact on learning performances in an undergraduate course. They define social gamification as the combination of gamification and social networking to create compelling socially driven user experiences (e.g., blogging, questions and answers, liking, friends, personalization (status/visibility)). They showed that social gamification induces better results for all types of assessments. Da Rocha Seixas et al. (2016) were also interested in the impact of badges on learners' performances, and the results indicate that their performance was improved. Landers et al. (2017) studied the impact of leaderboards on task performance and highlighted the interest of this gaming feature in supporting goal setting. The results obtained by Domínguez et al. (2013) are more nuanced considering the impact of gamification according to the type of learning task. The study conducted in a university course showed that gamification had a positive impact on the students' performances in practical assignments and on overall performance, but it had a negative effect on students' performance in written assignments and participation in class activities, although the students' initial motivation was higher.

Regarding learners' motivation, we can observe differences in the results obtained in several studies (Seaborn and Fels 2015). For instance, Hamari (2017) focused his study on the use of badges to increase learner engagement in the learning activity consisting of getting used to working with an application for online communities where one can share goods and services. Results show that learners who used badges were significantly more likely to post trade proposals, carry out transactions, comment on proposals, and generally use the service in a more active way. However, a related study conducted by Hanus and Fox (2015) showed that integration of a leaderboard and badges induces a lower level of motivation and lower

final exam scores for students, thereby showing a negative effect of this gamification feature.

Beside the education area where the focus is on learning performances and learners' motivation, another area of gamification is the persuasion area where the focus is on influencing attitude and behavior. The "educational component" is leveraged to persuade people to change their attitude or behavior (Bogost 2007; Fogg 2003). It is not surprising that this type of gamification has its roots in the corporate sector because changing attitude and behavior is one of the core activities of the marketing discipline. There are several studies that have reported changes in behavior when gamification strategies were used, but only a few report changes in attitude. Seaborn and Fels (2015) analyzed empirical findings of 31 studies. They reported that in 61% of the studies, gamification had a positive effect, but 39% had mixed results. In almost all cases (97%), the aim was to influence behavior of the participants. Unfortunately none of the 31 studies reports about attitude changes. Only behavior, learning performances, and/or engagement was measured. Hypothetically we would expect that attitudes should change if behavior changes by using gamification. An attitude is an evaluation of an object of thought. The focus of an attitude may comprise anything a person holds in mind, ranging from the mundane to the abstract, including things, people, groups, and ideas. Most researchers agree on this core definition according to Bohner and Dickel (2011). They also mention that researchers have long been using self-report scales, which directly ask a respondent to evaluate the focus of an attitude by checking a numeric response on single or multiple items. It is possible that the limitation of this method in measuring attitudes is the reason for researchers of the 31 studies not to examine attitudes. In another literature review of empirical studies on gamification of Hamari et al. (2014), psychological outcomes of 12 studies are reported. These psychological outcomes refer to perceptions, motivational affordances, and engagement toward a gamification application and not to the behavioral context where this

application is aimed at, for example, preserving energy in the household. Hamari et al. (2014) state that in only four studies, user qualities were believed to have an effect on attitudes toward gamification itself. All this suggests that there is a lack of research concerning attitude change by using gamification techniques. An exception is a study of Smith (2017) where a positive attitude shift is reported in a condition where students attended a gamified statistics course. Another one is reported by Bonvin and Sanchez (2017). Their study, based on the records of students' behavior of three classes, shows that gamification fosters collaboration among secondary students. Lastly, there are some studies – all on the area of sustainability – where attitude change using gamification is reported. Fijnheer et al. (2016) analyzed these (eight) studies where a gamified persuasive household energy application was developed – by implementing real-world processes *in* the design – in order to influence energy consumption of households. All studies report a positive behavior change, seven studies report a positive knowledge change, and six studies report a positive attitude change toward energy saving as well. The authors suggest the following gamification elements to be effective: gameplay (six studies), feedback (five studies), team

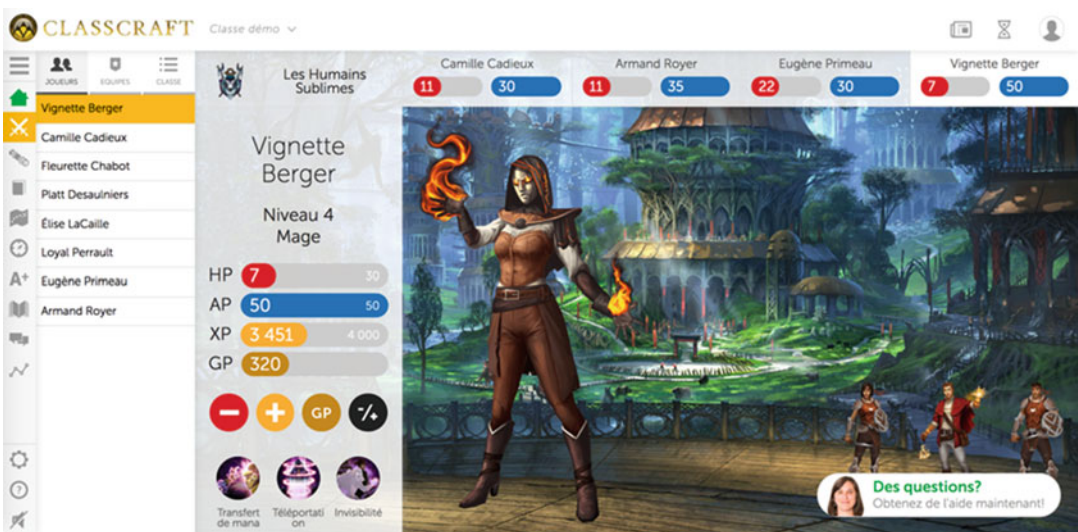
play and social component (three studies), and competition (three studies).

Examples

Since gamification emerged, the concept has been applied in various educational contexts (De Sousa Borges et al. 2014; Ortiz-Rojas et al. 2017) from primary to higher education. According to these meta-reviews, there is a majority of papers on gamification for higher education. Studies on gamification for primary and secondary education are less frequent (ibid.). Gamification has been implemented into Massive Online Open Courses (MOOCs) (Chang and Wei 2016), training, and lifelong educational programs. In the following, we describe three examples of gamified contexts.

Gamification of Classroom Management with Classcraft

Classcraft (Sanchez et al. 2016) is a mobile web-based application for classroom management (Fig. 1). Since Classcraft launched, more than 2.5 million active accounts have been created, and ongoing analysis demonstrates the game's efficiency in terms of students' collaboration (Bonvin and Sanchez 2017). Classcraft



Gamification, Fig. 1 Screenshot of Classcraft©

transforms the classroom into a role-playing game. Students are placed in teams and play as mages, warriors, or healers. In order to acquire powers, the players must meet teacher expectations by, for example, arriving to class on time, doing homework, and helping other students. Depending on its behavior, the player will win or lose gold pieces (GP) needed to customize their avatar, health points (HP), experience points (XP), and action points used to acquire powers. Randomness is another game mechanics that is leveraged in *Classcraft*. Once a week, the class starts with a random event that may have a positive or negative impact, such as losing or winning points, on every team. Randomness also manifests itself when, having lost all his points, the player must throw the “cursed die.”

Students progress in the game by exhibiting positive classroom behavior and attitudes such as collaboration with peers, thus acquiring powers and progressing their avatar. With *Classcraft*, a student who comes to class 5 min late may use the power of “invisibility” to avoid punishment. If the student does not have this power, the teacher, as gamemaster, deducts points. The loss of too many points causes death, which may mean a school detention or another punishment, depending on the rules set by the gamemaster. Students can also use their powers individually or collaboratively. For example, mages are very powerful and can often use their abilities to benefit their entire team. *Classcraft* is intended to foster student collaboration within teams. It is also designed to motivate students to comply with classroom rules of conduct.

Gamification and Enhancement of Sustainability

The inclusion of reality by using gamification principles in a gamified persuasive application can be an effective means to change people’s energy-related attitude (Fijnheer and van Oostendorp 2016). When people are highly engaged, they are apt to adopt the attitude that is promoted in the application (Ruggiero 2015). This can lead to a higher awareness of relevant factors involved in, for instance, energy saving. In effect, attitude may positively change and, as

such, subsequently trigger a change in energy-saving behavior itself. The assumed chain of events, higher awareness (more accessible knowledge)-attitude change-behavior change, is what gamified persuasive applications try to influence (Aronson et al. 2013; Chen and Chaiken 1999; Soekarjo and van Oostendorp 2015). The application *Powersaver* (Fijnheer and van Oostendorp 2016; Fijnheer et al. 2016) is used as an instrument of a larger research project that will give insight into what the influence of playing in the real world is on attitudes toward sustainability and on sustainable behavior in the long term. The focus is specifically on energy consumption in households by means of electricity and gas usage. The target is to contribute to the stimulation of individual sustainable behavior by studying how gamification can be a positive incentive for people to change their behavior regarding energy use at home. Therefore several gamification elements such as missions, levels, quizzes, narrative, competition, badges, and feedback are implemented. It aims to study whether transfer from game play to real-life behavior has a long-term character (Gustafsson et al. 2009a).

Powersaver (Fig. 2) is used in a household whereof the whole family is involved by implementing the gamification element cooperation. The navigation by the user is done by point and click on a tablet. *Powersaver* is basically an Internet page. It starts with an introduction of a story. This constitutes the narrative gamification element. A family arrives at a dilapidated country house where a professor had caused a failed experiment. Avatars of the family members are the central characters of the narrative. The family composition in the application is customized to the household. The family enters the main hall of the house that contains several locked doors. Behind each door a room is situated where a character in the form of a confused electrical device is placed. A cat (former pet of the professor) called Kyoto guides the family in the narrative. Every mission session the family is asked to enter a preselected room. Before the door opens a quiz has to be played. A quiz contains questions that will prepare players for the missions that are occurring in that specific room. When the family



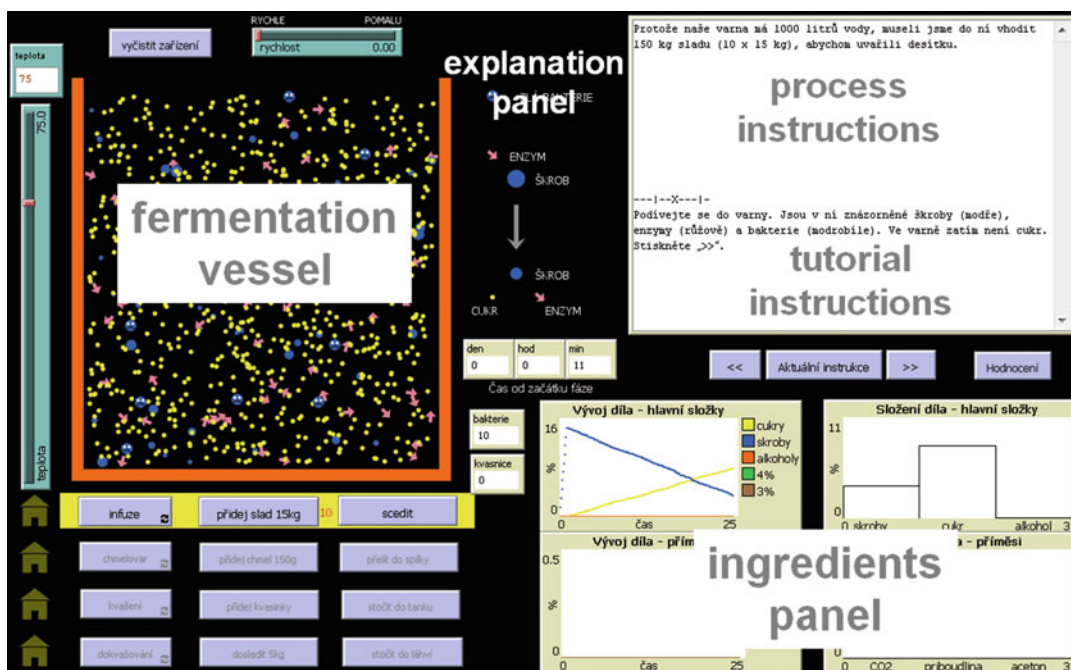
Gamification, Fig. 2 Screenshot of powersaver

enters the room, a character in the form of a device that is in a confused state is shown. The family has to accomplish, in one and a half or two and a half day, missions to help the device to get in a normal state. All missions (e.g., washing clothes on low temperatures) take place in the real world. In time the missions are getting more difficult. The total period of using the system is 5 weeks. *Powersaver* has 13 missions, 8 quizzes, and an end battle/scene. These missions are an important gamification element and represent the real-world processes that are incorporated in the persuasive system. A real-time connection between the household energy meter and computer server is accomplished by data loggers with an Internet connection. Energy consumption is monitored a month before the application starts to set a good baseline of average energy consumption. Another gamification element is feedback that users are getting on energy use and savings, the results of the quizzes, and achievements of completed missions that are displayed with badges. Another implemented gamification element is competition. A household is in competition with seven virtual households, but assumes to play against real households.

An Example from Higher Education: Brewing Beer

Brom et al. (2017) studied with university students a complex process (brewing beer) in a computerized simulation. In a 2-h interactive simulation, they learned how to brew beer. The simulation focused on the boiling, fermenting, and conditioning phases of the brewing process. The graphical interface (Fig. 3) showed different panels, e.g., an animation panel showing the content of fermentation vessels, graphs, and histograms showing the amount of ingredients, buttons for controlling the processes, etc. They examined adding several gamification elements to the simulation like providing a clear game goal, increase of the freedom of choice (of tasks to work on), points, virtual currency, and including verbal feedback.

No differences between the gamified simulation and control versions were detected nor concerning learning outcomes nor concerning affective-motivational aspects. Also 1 month after playing the simulation, no differences were found. However, one significant difference concerned perceived difficulty: the gamified



Gamification, Fig. 3 Screenshot of graphical interface (Brewing Beer)

simulation was *perceived* to be easier than the control versions. Maybe the gamification seduced learners to a light learning conception with the risk to engage only in superficial learning, and failing to help learners to engage in deep learning (Conway 2014).

The null results of this study may indicate that the gamification did not succeed in increasing learning nor motivation perhaps caused by increased distraction due to the many extra details in the user interface. An important implication of their study is that one should be careful with adding gamification elements (Conway 2014; Seaborn and Fels 2015). Researchers should also consider individual characteristics like attitude toward ICT, ICT experience, and background knowledge.

Criticisms Levelled

– Gamification Versus Ludicization

Etymologically, the word gamification reflects the idea that it is possible to “create” or to “fabricate” the game. Therefore,

gamification is considered to be an automatic and non-problematic transformation (Silva 2013) often referred to as *pointsification*, i.e., gamification that exclusively relies on points, badges, and leaderboards (Kapp 2012). However, right in 2011, Deterding et al. (2011b) state that gamification consists in addressing playfulness (the experiential and behavioral dimensions) and in using these dimensions for the design of structures with ludic affordances. As a result, some authors suggest to adopt the word *ludicization* in order to focus not on the artifact but on the situation that takes place when an individual accepts to play (Genvo 2013; Sanchez et al. 2016). Therefore, play is considered to be *performative* (Sanchez and Mandran 2017), and play depends on the *lusory attitude* (Henriot 1969) of an individual who accepts the arbitrary and artificial rules of the game. According to this approach, there is no specific game element that can be used to make a game (as supposed by gamification), but it is possible to subtly combine elements in order to design a learning context where play can take place

(ludicization). The term ludicization is based on *ludus*, the Latin root of ludicization, which means both game and school work. In addition, the suffix “-icization” does not mean that it is possible to “create” the game, as suggested by the suffix “-fication” (*facere*) of gamification, but primarily that it is possible to transform the situation (Sanchez et al. 2016).

– **Short-Term Versus Long-Term Effects**

Beside the difficulties faced by researchers to assess the results of gamification, some studies show that the results of gamification may not be long-term, but instead could be caused due to a novelty effect (Hamari 2017). Due to the lack of longitudinal studies, this issue remains unclear and needs further investigations (Seaborn and Fels 2015).

– **Edutainment and the Chocolate-Covered Broccoli Approach**

Gamification is often considered to belong to the edutainment trend. Edutainment considers that educational objectives should be hidden to students or, at least, “sugar coated.” This approach is in line with the *maxime placere et docere* (to please and teach) (Horace 65-8 bc) and the humanist learning tradition expressed by Erasme (1467–1536). Criticisms expressed by Bruckman (1999) underline the risk that instructional game-based techniques that consist of just covering games over the learning content in order to make the learning content more palatable have become synonymous with the *chocolate-covered broccoli* approach of teaching (Habgood and Ainsworth 2011).

– **Behavioral Patterning and Ethics**

Gamification is a process by which end-user engagement and behavior can be shaped and directed. As a result, by applying normative constraints, gamification has the potential to be used as an instrument of coercion. Therefore, there is a risk to apply techniques leading to lose the emancipatory aim of education. This ethical issue seems not yet being addressed by researchers and is not often mentioned in research papers.

Current Trends in the Gamification Field

Although gamification is a term still used with diverse meanings and grounded on underdeveloped theoretical foundations (Seaborn and Fels 2015), research in the educational field is very active. Below, we present two current trends of research in the gamification field: the inclusion of reality by using gamification elements in a gamified persuasive application and adaptive gamification.

Inclusion of Reality by Using Gamification Elements in a Gamified Persuasive Application

Usually in gamification processes, gameplay elements are implemented in real-world processes or activities to stimulate behavior (Deterding et al. 2011a). In some research projects, a different and novel approach of integration of gamification is chosen. Real-world processes, e.g., household energy-saving activities, are implemented *in* the design of a gamified application. In this approach, situated learning experience is provided by integrating a persuasive simulation with gamification elements such as missions, levels, quizzes, narrative, competition, badges, and feedback. The learner applies his/her knowledge directly to solve problems (Gustafsson et al. 2009b) by performing tasks in the real world that are at the same time directly interconnected to the gameplay in the digital world. The inclusion of reality by using gamification elements in a gamified persuasive application can optimize the transfer of knowledge from the application to reality (Kors et al. 2015). Some gamification research suggests that the integration of serious games into real life could have positive effects on attitude and behavior (Gustafsson et al. 2009a; Hamari et al. 2014). It can be assumed that implementing real-world processes, instead of simulated/fictive processes, in a gamified persuasive application will have positive effects. It is important to note that in this novel, reversed approach, it is *not* the case that gameplay elements are included in real-

world processes. Instead, real-world processes, e.g., household energy-saving activities, are included in the application itself. *Powersaver* described above illustrates this approach. This approach tries to optimize the transfer between the digital world and the physical world. When the transfer is optimized, the application can be more effective in change of attitude and behavior (Kors et al. 2015). At the moment of this writing (November 2017), this first study with *Powersaver* is in its ending phase, and the results are promising. Households in the gamified condition have reduced up to 21% in energy consumption during the intervention and have a reduction on average of 10% in the period after the intervention. Households in a control condition that used the Powersaver energy dashboard – the Powersaver application without gamification elements – didn't change their behavior in energy consumption. So the essential difference between both conditions involved the gamification elements (Soekarjo and van Oostendorp 2015). In a recent, comparable project Casals et al. (2017) report similar positive effects.

Adaptive Gamification

Gamification in itself still lacks the adaptivity required to reach a wide range of users (Vassileva 2012) and to meet learners' game mechanism preferences (Harviainen 2014). In fact, users show different types of engaged behaviors when interacting with online environments (Bouvier et al. 2014) and different player preferences (Bartle 1996). According to Harviainen (2014), "the very elements that motivate some learners (e.g., competition) are the ones disliked by others, and also those that when taken to excess, cause problems." Research in the gamification field tends to consider the role of individual differences, for example, personality differences (McCrae and John 1992), player types (Yee 2006; Hamari and Tuunanen 2014; Monterrat et al. 2015), and demographic differences (Koivisto and Hamari 2014), in the perception and effects of the gamification process. Furthering this line of research could refine the understanding of user-related factors

(Hamari et al. 2014) and build foundations for adaptive gamification.

Still little is known on *how* to adapt game elements to users in learning environments and more generally in computer-based environments. The work conducted by Monterrat et al. (2015) is one of the first to address this issue. They integrated and adapted gaming features in a learning environment according to player types. The exploratory study they conducted showed the potential of the adaptation of gaming features for enhancing learners' motivation. This supports the hypothesis that there is a need for adaptive gamification of learning environments. In a more recent study, Monterrat et al. (2017) also showed that the users' activity can help to predict their profile that can be used for the adaptation process. In their study, the adaptation process did not improve learners' engagement as expected, but it draws a path for future research toward an adaptive approach for learning environment gamification.

Cross-References

- [Game-Based Learning](#)
- [Games in Higher Education](#)
- [Games, Simulations, Immersive Environments, and Emerging Technologies](#)

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Gender Difference in Self-Efficacy for Computational Thinking in K-12

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Synonyms

Capacity beliefs; Computer science; Gender gap; Primary and middle school; Science education

Introduction

The introduction of computational thinking (hereafter, CT) and coding in primary and secondary schools (hereafter, K-12) is one of the novelties introduced by recent educational policies in many countries of the world. The aim is to prepare students for a world strongly influenced by information technology (Wing 2006; NRC 2010, 2011) and to encourage a culture of creation and production rather than the mere passive use and consumption of technology. At this level of education (K-12), the inclusion of CT appears to be:

- An unprecedented opportunity, as for the first time, this subject is being introduced among the curricular subjects for younger children (European Schoolnet 2014).
- A strategic challenge for educational institutions, as (1) there are still low enrolment rates

for students in the STEM area (Science, Technology, Engineering, and Mathematics) in many countries (OECD 2015a); (2) there is a large gap in inscriptions for the STEM area between males and females, to the detriment of the latter (OECD 2015b).

International research literature on computer science education continues to confirm a worrying underrepresentation of women in the information and technology sectors, with disturbing results about gender impact (OECD 2015b). The use of computers and ICT-related activities have been seen as a “male domain” in the recent past, and this interpretation still remains today, despite slight improvements in the treatment of the different genders (Pechtelidis et al. 2015).

The crucial age for the choice of studies and careers is between 13 and 17 years of age; this period presents a crossroads, in most cases with no return path, in which teenagers definitively choose what course of study to pursue. The data generally record the abandonment by girls of science subjects (such as natural sciences, engineering, and technology) to pursue other choices, usually in the humanistic field. Looking more closely at some figures (the EU area is taken here as an example), one sees that the number of female graduates is 55%; but attending to data from the scientific area, it is notable that women graduates in computer science are only 22% compared to 78% male. Even in advanced research studies, such as at PhD level, although the number of women is higher than men, they are still a numerical minority in the fields of engineering and computer science. In the workplace, the numbers drop drastically: the percentage of women responsible for IT systems is 27%, and this drops drastically (to 9.6%) among those responsible for hardware engineering. Women hold only 5.8% of senior university academic positions in the fields of information technology, engineering, and technology (European Schoolnet 2014).

Although there is a vast literature on gender difference and ICT in general, an alarm has been issued by many parts of the scientific community (NRC 2010, 2011; Grover and Pea 2013; Wing 2017) that there is an international research deficit

on CT in K-12 (which has suddenly become a curriculum subject in many countries of the world). This new area requires that investigation shift from ICT to Computer Science Education, taking into account that some areas are still untouched by gender studies, as are some other fields such as special educational needs and CT assessment for this age group. Therefore, it seems even more urgent to introduce gender analysis of CT activity on several fronts of research and educational practice, as children aged from 6 to 12 have already formed their knowledge, ideas, beliefs, and habits regarding technologies, and these experiences will show their effects, after the age of 12, in the choice of studies and careers.

Research in the educational field (and not only there) over the past 50 years has shown how critical beliefs and attitudes are to the future choices of students. It is important to know and investigate the cognitive and metacognitive aspects (functions, processes, and strategies) that are implemented in this phase of development (6–12 years). It is equally important to understand and investigate the system of values that boys and girls build around their learning experiences, including those that are not purely cognitive but also motivational and affective, such as the idea of CT a student has; the idea the student has of himself/herself in relation to this subject; his/her convictions or doubts about their ability to use coding; the security he/she has in dealing with problems in the subject and persevering over time. Clearly, there is a pressing need to achieve a lucid theoretical and practical understanding of CT learning in K-12.

This work focuses on the effects of gender differences in self-efficacy among K-12 students on their beliefs and their ability to succeed in specific situations (Bandura 1997). Given that self-efficacy is a vast area of research, some particular aspects will be analyzed in depth in the following sections: definition, dimensions, sources, measures of self-efficacy, and gender research in academic performances (see section “Self-Efficacy in Gender Difference”); finally, attention will be focused on situations related to gender in self-efficacy beliefs in K-12 students

when they are learning CT (see section “[Related Work: Computational Thinking, Gender Difference and Self-Efficacy in K-12](#)”). The conclusions are focused on the gender research recommendations in self-efficacy for CT in K-12 (see section “[Conclusion](#)”). It is important to underline that both self-efficacy and academic literacy are highly context dependent and, therefore, difficult to measure (Bandura 1997; Zimmerman 2008; Eccles 1987). However, research conducted so far shows that both of these measures influence student learning outcomes (Bandura 1997; Hattie 2012). At the point where research has arrived, presenting the state of the art on gender difference in self-efficacy for CT in K-12 is particularly difficult for the following reasons:

1. Being a recent phenomenon in K-12, this specific area is still little investigated. Given the small amount of data available, comparisons and generalizations of the results are difficult to achieve, not only because of differences among the organization of various school systems and their various sociocultural contexts but also because of different understandings of the meanings of key terms (including “computational thinking,” “coding,” and “programming”). These terms are sometimes used with separate meanings and sometimes synonymously. Their definition is still the object of heated discussions within the international community and among national scientific communities in their respective countries (NRC 2010, 2011).
2. In the research literature, there are several instruments to detect self-efficacy that have been validated internally but not externally for this specific age range on computational thinking. For example, there are some validated questionnaires in English for programming but for the age groups of the last grades of secondary schools and early university years in computer science (see section “[Related Work: Computational Thinking, Gender Difference and Self-Efficacy in K-12](#)”). The same questionnaires use different versions of self-efficacy (see sections “[Self-Efficacy in Gender Difference](#)” and “[Related Work: Computational Thinking, Gender Difference and Self-Efficacy in K-12](#)”) and are often modified, customized, and translated according to the needs of the research context. On other occasions, the items of the instrument to which the students have responded (whether a questionnaire, interview, or other) are not even reported when the research is published but only a general description: this makes it problematic to compare the results. Added to this, these tools do not use all the resources of self-efficacy, as it will be described in the next paragraphs (see section “[Self-Efficacy in Gender Difference](#)”). Very often they are adapted and focused on a specific digital learning environment (like Scratch, Alice, Beebot, and similar) more than on cognitive, emotional, and social aspects of the self-efficacy of programming. Even the translation of the same questionnaire into different languages can lead to alterations in self-efficacy values, linked to different emotional reactions by the students (Aamir et al. 2017).
3. Up to now, the learning of CT has been a niche subject. Usually, it has been limited to laboratory experiences carried out in a few weeks or at most a few months, mainly in noncurricular hours and sometimes in laboratory activities independent from the schools, such as “summer camps” or similar initiatives of which it is not known whether they were followed up or remained isolated moments of study (see section “[Related Work: Computational Thinking, Gender Difference and Self-Efficacy in K-12](#)”).
4. The introduction of CT in K-12 appears to be inserted into the curricular activities of different countries with a notable slowness (Royal Society 2012), due to the fact that some countries are lacking teachers of the discipline. To obtain a complete picture, research must not be limited to the self-efficacy of children without taking into consideration the self-efficacy of their teachers too. The efficacy beliefs of teachers influence their instructional practices and their students’ achievement (Bandura 1997). These considerations demonstrate that

it is problematic and premature to present a complete picture on the issue of gender difference in learning CT in K-12, compared to other school subjects that have long traditions of research (such as writing, mathematics, and the sciences) and where self-efficacy findings are based on annual curricular teachings extending for decades across all grades of school.

Self-Efficacy in Gender Difference

Self-Efficacy: Definition

Self-efficacy, a construct developed by Bandura (1977) within the framework of social cognitive theory, refers to “*people’s judgments of their capabilities to organize and execute courses of action required to attain designated types of performances*” (Bandura 1986, p. 391). Nearly 40 years of research have amply demonstrated that self-efficacy beliefs are related to cognitive, motivational, affective, and behavioral outcomes in a variety of domains (Bandura 1997). In the school setting, self-efficacy refers to the beliefs that students have in their ability to perform required learning tasks. Students with high self-efficacy persevere longer, engage in the search for a deeper meaning in learning tasks, report less anxiety, and have higher results at school (Bandura 1997; Pajares and Schunk 2005). Students’ self-efficacy has been shown to predict the results achieved in various academic areas, such as mathematics, science, and writing (Usher and Pajares 2009; Pajares 2003). Just as self-efficacy predicts students success in specific domains, students’ beliefs influence their ability in self-regulated learning, which indicates how students are able to implement self-regulated strategies in school activities (Zimmerman 2008).

It has been demonstrated that self-efficacy beliefs are correlated with students’ academic motivation, self-concept, goal orientation, performance, and anxiety, as well as attitudes to success and risk of dropout (Caprara et al. 2008; Zimmerman 2008). Given the central role played by personal self-efficacy beliefs as determinants of academic success, much research in education

has begun to focus on the processes by which these beliefs are formed.

Bandura (1997) considers that personal beliefs formed during primary schooling are likely to be the keystone on which subsequent beliefs of effectiveness are built up. However, as Usher and Pajares (2009) point out, while there is much research on self-efficacy beliefs for age groups ranging from 11 to 17 years (Bandura 2006), there are only a few studies that have investigated sources of self-efficacy among students at the primary level, a period in which children are particularly receptive. Much remains to be understood about gender differences for this age group, for which the available data are still insufficient.

Self-Efficacy and Related Concepts

One of the best ways to define self-efficacy is to distinguish it from related concepts with which it can be confused (Bandura 1997; Zimmerman 2000). Self-efficacy does not refer to a perceived skill but to what a person believes they can do with their abilities under certain conditions.

Self-efficacy also does not refer to beliefs about the ability to perform simple and trivial acts but rather to beliefs about the ability to (re) organize one’s abilities in certain changing and challenging situations.

This construct investigates what an individual is able to do and not what he/she would like to do (intention) or what he/she is used to doing (habit). Intentions indicate what he/she will probably do (even if intentions are influenced by a series of factors that also include self-efficacy), while habits are courses of actions already in place and do not, accordingly, represent challenging situations.

Self-efficacy is not self-esteem. Self-esteem concerns what persons believe about themselves and how they feel regarding what they believe about themselves. This construct concerns wider areas of the life of the individual and is influenced by the importance that the determined field of action has in his/her existence. Self-efficacy, on the other hand, is related to a specific domain and to actions aimed at solving a problem. For example, a researcher investigating self-esteem would ask a student “*How good are you in computer*

science”, while one investigating self-efficacy would ask “*How certain are you that you are able to detect the variables of this problem?*” (Zimmerman 2000).

Finally, beliefs of self-efficacy are not expectations of results; Bandura (1997) believes that expectation theorists have isolated commitment as the sole reason for a resulting performance; they concentrate on the amount of effort expended in habitual activities, conceptualizing commitment as neither mutable nor sensitive to challenge. Self-efficacy, on the other hand, directs subjects to make an effort to understand the quality of their performances and in particular the beliefs that lead them to apply themselves in situations that require perseverance.

Self-Efficacy: Multidimensional Concepts

Self-efficacy varies on diverse dimensions that regard beliefs of magnitude, strength, and generality (Bandura 1977).

Magnitude refers to the difficulty of the task. People can vary their level of self-efficacy depending on how much they believe a particular task is easy or difficult for them. This level can also vary depending on the need of people to face challenges, as some may be motivated to engage concretely in a challenging activity, while others avoid difficulties because they do not feel able to face them.

The strength of expectations refers to the effort that a person is able to activate for a long period of time and in the presence of obstacles. It follows that this dimension does apply to the ability to perform a known trivial and occasional activity; it applies rather to whether a person is able to persevere continually over time, even in the presence of difficult conditions. For example: a strong expectation cannot easily be extinguished by negative experiences, while weak expectations may crack at the first hurdles or adversities.

Generality refers to the ability to transfer self-efficacy from one area to another: for example, *from algebra to statistics* (Zimmerman 2000). This dimension takes into account the self-assessment individuals make regarding their self-efficacy in both a wide range of activities and also in restricted areas. Generality also includes the

following subdimensions: the degree of similarity of the tasks, the modalities of expression of the capacities (behavioral, cognitive, and affective), the characteristics of the situations, and the characteristics of the persons to whom particular behaviors are directed.

In the contexts described above, when data on self-efficacy are to be collected, it is important to plan for a specific behavior to be measured in the performing of a precise task, to predict what obstacles might arise to be dealt with through interventions and whether the purpose is to include transfer components or not.

Sources of Self-Efficacy

In general, Bandura (1997) has theorized four sources of self-efficacy that can influence people’s beliefs and have a mediated effect on behavior: performance accomplishments, vicarious experience, verbal persuasion, and emotional arousal. At the educational level, it is important to understand the sources of self-efficacy and to intervene in them, both to identify the needs of the students and to create or improve their expectations of self-efficacy and then allow the students to implement a specific behavior to achieve the desired results.

Performance accomplishments refer to one’s own experiences and to the history of personal behavior or performance achieved. These are also called enactive mastery experiences. They are indicated by Bandura (1997) as the most influential sources of information, when compared with others, since they provide indicators of the beliefs inherent in the abilities possessed by a subject. Bandura (1997) explains that information on self-efficacy derives both from the performance implemented in the context, including the characteristics of the task, and from the self-efficacy beliefs already held.

Successes help to improve self-efficacy beliefs while failures weaken them, especially if they occur before a sense of effectiveness is established, particularly in the stages of cognitive, affective, and social development of the child. However, Bandura (1997) emphasizes that a strong sense of self-efficacy requires learning over time, in order to develop the more sophisticated components of this construct, such as the

sense of resilience, as well as developing knowledge of the rules and strategies necessary to deal with difficulties (Usher and Pajares 2009). For example, it is important to link successes with persevering efforts, if a person wants to avoid discouragement in the face of possible failures.

In this perspective, difficulties are in themselves a learning opportunities, if they are interpreted by the subject (or the subject is guided to recognize them) as moments for transforming their weaknesses into strengths and to develop the ability to control events.

Vicarious experience is the second source of self-efficacy; it is as influential as the first and includes experiences observed by the individuals themselves (Bandura 1997; Usher and Pajares 2009). This resource refers to learning by modeling learning and explains the extensive knowledge that children acquire by observing other people, both in their presence and through the media. This learning is not automatic: what the child learns is influenced by the aspects of observed behavior to which he/she pays attention and his/her ability to interpret and remember. Children's vicarious experiences are based on models that function as organizing principles of their knowledge and behavior, from which they draw conclusions to apply to their own behavior and their own predictors. The more the model (the other person observed and taken as a reference) has the desired characteristics, the more likely it is that the observations will have an impact on the child. Self-efficacy is particularly sensitive to vicarious experiences, especially when children (or adults) are inexperienced or not confident about their abilities (Bandura 1997). The models taken as reference become a source of inspiration against which to measure and self-evaluate one's own abilities. Observers learn knowledge, skills, and coping strategies by understanding how effective models behave (Bandura 1986). Hence, self-efficacy can be influenced and modified by the models observed by the child, who can subsequently transform its own behavior. If the observed models display characteristics such as trust, perseverance, and resilience to difficulties, that can instill a higher sense of effectiveness in comparison with models who show signs of

distrust, self-doubt, and avoidance of difficulty (Zimmerman and Ringle 1981) or that carry out tasks too easily, without ever encountering problems. From gender research, it emerges that both women and men are particularly attentive and susceptible to models whom they believe to be credible and worthy of trust; although, it should be noted, women in the scientific-technological sector complain about the lack in their experience of female models to inspire them (Zeldin and Pajares 2000; Usher and Pajares 2009).

The third source is verbal persuasion. It is a weaker factor than the first two (performance results and vicarious experience) (Usher and Pajares 2009). Verbal persuasion can be defined both as verbal feedback from others and as instructions provided by texts for self-learning activities. Verbal (and social) persuasion is an additional resource for reinforcing an individual's beliefs that he/she possesses the skills to achieve the desired goals. In difficult situations, one is more likely to maintain a good degree of self-efficacy when others express confidence, rather than doubt or discouragement, in the abilities of the subject. However, social persuasion can also cause negative effects, either through negative feedback or by raising unrealistic beliefs about the skills possessed (Bandura 1997).

The fourth and final source of self-efficacy is emotional and physiological experiences. Individuals also estimate their self-efficacy on the basis of somatic information related to emotional and physiological states (Bandura 1997; Usher and Pajares 2009). Stressful or particularly demanding situations can provoke physical and emotional reactions which, if not controlled and elaborated, can be interpreted as signs of vulnerability or dysfunction and thereby influence self-efficacy judgments of one's (in)competence and/or (un)controllability (Benson 1989). For example, it is difficult to avoid perceiving states of tension, nervousness, fatigue, and pain, which are alarm bells of our physical and mental system when under stress, but if these states are interpreted as signs of insecurity or personal incapacity, they may create distortions in the processing of information and result in negative judgments of self-efficacy. Furthermore, self-efficacy is influenced by the way

emotional states are perceived and evaluated. For example, educational interventions can guide students to recognize physical states and emotional excitement and to rework their feelings constructively in order to develop forms of resilience (Bandura 1997). Such interventions can also help students to recognize wrong representations and to modify mistaken cognitive representations and nonfunctional interpretations.

In the school environment, the influence of anxiety on self-efficacy beliefs has been documented, above all, for mathematics, which is a source of common concern for students, especially for girls (Bandura 1997; Usher and Pajares 2009). Studies have amply documented that there is no direct relationship between past experiences and anxiety; this connection necessarily has to go through a low sense of self-efficacy. If the reasons for the failure are attributed to external causes, this will not affect the self-efficacy, and therefore, the levels of anxiety will remain unaffected. On the contrary, if the cause of failure is attributed to personal factors, self-efficacy will suffer and anxiety levels will tend to increase. Since female students are more insecure about their skills in the discipline, they are more likely to set up mechanisms of the second type (Bandura 1997). It follows that as anxiety correlates to poor scholastic performance; this relationship generally vanishes or decreases when one works on the rules and strategies of self-efficacy representation, on dysfunctional thought patterns, and on the processes of interpretation.

Measuring Self-Efficacy: Specific and General

Bandura (1997) distinguishes three levels of self-efficacy measurement: (1) The most specific measurement is the level of one's sense of self-efficacy for a particular performance in the presence of a specified set of conditions. (2) The intermediate measurement level regards the sense of self-efficacy for a category of performance within a particular sphere of activity in the presence of a set of conditions that share common properties. (3) The most general and global measurement level is of convictions of personal effectiveness without specifying the activities or conditions in which they will be employed. In this vein, some

researchers have also worked on the existence of more general self-efficacy beliefs. In this case, these are measures developed on the concept of general self-efficacy, which Judge et al. (1998, p. 170) defines as the personal beliefs that people have of their ability to "perform in a variety of different situations", while Sherer et al. (1982, p. 664) defines it as a suitcase of beliefs [of self-efficacy] that "the individual carries into new situations".

In particular, there are the three scales most used in research, which were designed by Chen et al. (2001), Schwarzer and Jerusalem (1995), and Sherer et al. (1982). These scales have proved to be reasonably good predictors of self-efficacy performance in a wide variety of measurements and in a wide range of fields (educational, clinical, health, and organizational), showing good internal consistency and good test-retest reliability.

Related Work: Computational Thinking, Gender Difference, and Self-Efficacy in K-12

The next section ("[Computational Thinking: A Multifaceted Concept](#)") introduces some definitions of CT to delimitate the field of research that is examined in the following sections, despite the fact that the concept is multifaceted. Section "[Gender Difference in Computational Thinking](#)" is devoted to research on gender differences in CT in K-12, organized according to the elementary and middle school level. With the same organization, section "[Gender Difference in Self-Efficacy in Computational Thinking](#)" focuses on a series of studies that investigated gender differences focused on self-efficacy and how self-efficacy beliefs influences the experiences of children and girls on computational thinking.

Computational Thinking: A Multifaceted Concept

Before proceeding with the presentation of studies concerning gender differences, it is necessary to understand what is meant by CT and the difference with other terms such as "coding" and "programming," sometimes used with different meanings

and sometimes as synonyms. In this work, CT is interpreted as complex thought process (Wing 2006) in which “programming” and “coding” constitute two important aspects. “Programming,” in particular, refers to the analysis of a problem, the design of a solution, and its implementation. “Coding,” on the other hand, represents only the implementation phase of the solution by means of a particular programming language.

The CT definition is still under discussion in the international scientific community (NRC 2010, 2011). Mishra et al. (2013) underline how despite the strong interest of different countries regarding computational thinking, there are still many problems and challenges to be addressed to integrate CT in the school curriculum. The first of these concerns the definition of CT; next it is necessary to understand what are the attributes and the concepts underlying the CT, how to evaluate them, how to teach them to the students, how to train teachers so they can effectively integrate CT in their classes, and finally the types of research that must be done to promote the inclusion of CT at school.

Wing uses the term “computational thinking” as shorthand for “thinking like a computer scientist” (Wing 2006) and, more specifically, the thought processes involved in formulating a problem and the description of its solution in such a way that a person or a machine can effectively carry it out (Wing 2017).

Mishra et al. (2013) do not offer a common definition of CT but propose two perspectives of this concept; at the micro level, CT can be seen as teaching how to program a computer, using specific programming languages; at the macro level, CT can be seen as a set of “ways of thinking”, such as systems thinking, problem-solving, algorithmic thinking, etc.

Soman et al. (2012) highlight how the processes activated in CT concern the decomposition of a problem into smaller and easier subproblems, the recognition of patterns, the definition of abstractions, the choice of the resolver algorithm, the data analysis, and presentation of the work carried out. Wing (2017), in particular, emphasizes abstraction is the most significant process, by means of which even the most complex

problems can be addressed. However, it is important to bear in mind that the Wing’s definition is general and refers to adults, since the cognitive process of abstraction matures around the age of 14.

Fristoe et al. (2011), in a research article with middle school girls related to programming environments, maintains that the age from 11 to 13 years is a key moment in which to involve students (male and female) in programming environments, because most of them have the cognitive ability to engage in abstraction and reflection. In addition, the students are still in the process of exploring their own identity and the girls, in particular, still evaluate positively the activities of designing computer games.

Other researches, based on Brennan and Resnick (2012) model, used in order to analyze students’ performance in terms of computational thinking, underline how for most of them the process of abstraction is not clear.

Brennan and Resnick argue that CT can be evaluated in three ways: CT concepts (concepts used by the programmer, such as the concept of variable, loop, etc.), CT practices (practices used during the programming process), and CT perspectives (students’ understanding of themselves and the technological world around them, including questioning the nature of technology, the reuse of code and the concepts of abstraction and modularization).

As argued by Lye and Koh (2014), the majority of studies that used this framework explored issues related to CT concepts; yet it seems there is a gap in the research related to CT in K-12, especially regarding the dimensions of CT practices and CT perspectives (Grover and Pea 2013), areas that include the most important processes of computational thinking, such as abstraction.

Taking into account that the scientific community has not reached a common agreement on CT yet and that, in the meantime, many research projects relate to different aspects of computational thinking, it follows that research on gender differences, including those on self-efficacy, suffer from the same problems. The next sections move precisely in this direction, presenting the main research results in the field of gender differences

in CT and subsequently, in greater detail, self-efficacy in CT laboratories for primary and middle school students.

Gender Difference in Computational Thinking

Primary School

Several CT studies that especially investigated programming, such as the creation of computer games, motivational aspects, and learning strategies, did not report important differences between males and females. For example, Hsu (2014) in a US research work concerning gender differences in games creation with Scratch, carried out with primary school students, showed how both girls and boys have significantly improved their programming concepts and benefit from programming laboratories. Therefore, there are no gender differences in terms of programming concepts, even if the girls seem to better master the concept of counting loops. Also Vos et al. (2011), in a study conducted with 235 primary school students from the Netherlands, analyzed the difference in intrinsic motivation and deep strategy use by proposing two activities: in one, the children built their own game, while in another, they used games made by others. The research results showed that allowing children (male and female) to build their own games led to significant improvements in intrinsic motivation and deep strategy use compared to the use of games already made by others. In particular, this study found no gender differences in perceived competence, interest, or use of deep learning strategies.

However, other research, which widened the focus of investigation, underline some gender differences, highlighting how girls seem to have a more contextualized view of technology.

Mawson (2010), for example, in a research conducted with children aged 5–10 in New Zealand highlights how girls find it more difficult to define what a technology is than do boys. Girls seem to have a broader and contextualized view of technology and have conflicting views about the value of the same for society. Boys, on the other hand, have a more positive attitude than girls towards technology and its usefulness. Elvstrand et al. (2012) and Hallström et al. (2015), in two

research projects carried out in Sweden with first-year primary school children, which aimed to observe pupils while they built their own games, both with LEGO and poor materials such as ropes, cans, and tubes, observed that girls, when they use technologies to build something, often have a very specific purpose in mind, such as creating an object to be used in everyday life, while boys see the construction process itself as the main purpose of the activity. Research with primary school children conducted in Finland (Virtanen et al. 2015) and in the USA (Brunner et al. 1998) demonstrate that girls are particularly involved in useful and meaningful projects that have connections with everyday life, for example, the construction of useful and decorative artifacts for their homes, while boys appear more experimental and tend to construct objects for their own sake (Hsu 2014). In addition, girls tend to create games contextualized in realistic worlds, while boys prefer to make adventure games in fantastic environments.

Girls' attention to context (attending to the purpose for which they are using a technology and to the usefulness of the task) leads to another difference with boys, related to problem-solving approaches.

Research conducted in the Netherlands by Heemskerk et al. (2009) concerning the use of ICT underlines how females, in addressing a new task, prefer, more than males, clear instructions and collaborative activities, while boys prefer, more than girls, less information about the task, but a certain level of competition. Moreover, females seem to prefer activities that require greater creativity, while males require more dexterity. Also Ching et al. (2000), in a study conducted in the USA that involved students aged 10–12 in developing computer programs noted how boys prefer to address problems and solve them on their own, while girls prefer to be led and participate in more collaborative environments in which they can share with others what they do.

A study conducted by Kowiyah and Mulyawati (2018) with primary school students in Indonesia about the ability to represent in mathematics found a strong use by children of figures and tables. The researchers show that boys get

better results during action planning; in fact, the use of tables and figures was concentrated during the problem-solving planning. The girls, on the other hand, get better results and show more use of tables and images, during the problem-posing phase, that is the phase of problem understanding.

Other research underlines the relation between students' performance and the particular software they use. Joiner et al. (1996), for example, in research conducted in the UK with children aged 10–11 does not find a relationship between boys' favorite software and their performance but a significant connection between the girls' favorite software and their performance.

The above-mentioned research explores gender differences which, extended and deepened, could provide useful information for teachers, who have to design their school activities to involve boys and girls to the same degree.

Middle School

With regard to middle school, research shows greater gender differences than at primary school. Despite the fact that some research, carried out especially in the mathematical field, does not show marked differences between males and females, Perez-Felkner (2014) in a US study with middle school students found that the perception of their scientific abilities decreases in girls aged 13–14 years and above. Perez-Felkner (2014) has shown that girls in the fourth grade are more likely to choose to continue in a scientific path, which they do not consider difficult. This result is reversed in the eighth grade, when 36% of girls say they do not want to continue in scientific studies, compared to 30% of boys; moreover, 56% of girls say that scientific subjects are too difficult, compared to 44% of boys. Other research tends to confirm this gender difference, which seems to start at adolescence and strengthen over the years (Eccles 1987). Sáinz and López-Sáez (2010) in research conducted in Spain involving 550 middle school students aged 12–16 point out that from the last years of middle school, females tend to prefer subjects and fields of study in humanistic and social sciences, despite having better grades in technology than males and the

various initiatives carried out by universities to encourage girls to care about technological studies. Sáinz and Eccles (2012), in a study conducted in Spain on ICT, also find great gender differences in middle school students. Sáinz and Eccles (2012), in particular, underline how these differences are affected by the concepts pupils have of their own computer abilities, as confirmed by other studies, which have shown that students' choices are affected by psychological factors such as hierarchy of interests, ability self-concepts, domain-specific self-efficacy beliefs, and perception of the costs and benefits of being involved in specific activities.

The research world also highlights another difference between males and females in middle school concerning the approach to the study of computational thinking. A study conducted by Werner and Denner (2009), with 126 middle school students in California concerning computer programs development, shows that females, more than males, try to solve problems by collaborating with others. Furthermore, their research shows that girls are more interested in learning CT when there is more emphasis on collaboration during the problem-solving process. The same result is also obtained by Baytak and Land (2011) who, in a study conducted in the USA concerning computer games design, report that the involvement of girls stimulates social interaction and the creation of a community around information technology.

Heemskerk et al. (2009), in a research conducted in the Netherlands concerning the use of ICT, and Fristoe et al. (2011), in a research conducted in the USA with middle school children about the learning environments to use to introduce students to programming, underline that girls seem to prefer educational games and tools that facilitate the cooperation and sharing of what they learn more than competitive environments.

As emphasized in the previous section, it is important that teachers take into account these characteristics of students during the design phase of laboratories on computational thinking. As highlighted by Vekiri (2010), in a research conducted in Greece with middle school students

on value and efficacy beliefs of males and females in information technology, and also supported by studies conducted in other countries, such as (Clarke and Teague 1996) in Australia and (Goode et al. 2006) in the USA, teaching computer science tends to be still teacher-centered and focused on the development of decontextualized technical skills, offering students few opportunities to collaborate and to be involved in exciting, creative, and significant tasks.

Gender Difference in Self-Efficacy in Computational Thinking

The previous section recounted various gender differences that have been revealed by research on computational thinking in K-12. This research concentrates mainly on middle school and is mostly concerned with the lower interest that girls compared with boys have in technical-scientific subjects. This section will investigate this phenomenon with particular attention to students' self-efficacy beliefs, apparently one of the major causes of gender differences in this area.

With regard to primary school, there is little research that investigates gender difference in the sense of self-efficacy related to computational thinking. However, there is research which reveals that from primary school, girls generally tend to have a lower self-efficacy and self-confidence than males in technology, as highlighted in the following studies.

Endepohls-Ulpe et al. (2012) carried out a study aimed at developing innovative pedagogical practices and learning environments which encourage girls to choose courses of studies and professions in the field of natural sciences and technologies. In the first phase of this study, students (boys and girls) who had already undertaken a course of study in a technological field were asked to think about the factors that encouraged or discouraged them in their educational choices. The study involved both engineering and non-engineering course students in Austria (average age 22) and Germany (average age 23). The first factor analyzed was "Intellectually based interest and high self-efficacy in science and technology" in primary school. In relation to this factor, both

males and females who study engineering recalled having been more interested and competent in science and technology than colleagues who did not study engineering. In general, boys valued themselves greater than girls; it seems that an interaction effect is present between gender and field of study; males who do not study engineering remember to have been more interested and competent in science and technology than females who do not study engineering, while this difference is not so high between males and females studying engineering. The findings of the study highlight how girls, in general, remember from their time in primary school a low level of self-efficacy and a lower intellectually and practically based interest in technical-scientific subjects than males. In addition, engineering students, compared to others, report higher self-efficacy and intellectually and practically based interest in technical-scientific subjects, and there do not seem to be major gender differences. These students, compared to those of nonengineering courses, also remember strong support from their fathers for their interest in technology.

Another interesting study is that carried out by Hallström et al. (2015), which aims to investigate how Swedish children aged 3–6 explore and learn technologies in games (children have free access to Lego and other poor materials such as ropes, cans, and tubes) and how their teachers frame these activities in their teaching. The study uses an ethnographic approach and is based on qualitative data collected through video-recorded observations and informal chats with children and teachers. During data analysis, the notes collected were codified and, after repeated readings, the codes were grouped into categories: construction play, purpose of construction, gender differences, self-confidence and teachers' activity. The researchers found no differences among children when they draw and create patterns at the beginning of an activity. However, during the experiment, which is a fairly new situation for children, boys are more active than girls, who distance themselves from the activity. The researchers believe that this result is connected with a lower degree of self-confidence in girls than boys. The

same difference in self-confidence was also noted in other circumstances, for example, when boys had to introduce themselves. In general, boys are more eager to try something new than girls, especially in relation to technology and science. During the construction of a tower with blocks, for instance, which is a nonstereotyped activity perceived as masculine, girls do not feel as involved as boys; indeed, in this situation, they become “helpers” of the boys.

Virtanen et al. (2015) make a similar finding. In fact, in an exploratory study on the differences in motivation between males and females towards technological education in a Finnish primary school, which involved 281 students of the fifth and sixth years, they found that boys had a higher level of self-confidence, more enthusiasm in the lessons, and more fun in learning how to use different tools than did girls.

However, other studies, such as the one conducted by Sinan et al. (2014), demonstrate that gender has no effect on the sense of self-efficacy. In their study, Sinan et al. (2014) aim at determining the science attitudes and the self-efficacy levels of 296 students from three primary schools in Turkey. For data collection, two scales were used: Science Attitude Scale and Generalized Self-Efficacy Scale. The research results showed that gender has no effect on science attitude and self-efficacy; instead, they showed the presence of significant differences between fifth year students and those of the following years, in favor of the latter.

In summary, gender difference in the sense of self-efficacy seems to start in primary school and continue in secondary school, up to university, where girls show less self-efficacy than boys, especially when having had less computer learning experiences. To confirm that, He and Freeman (2010) carried out research that aims to study the mechanisms through which gender influences the development of the general Computer Self-Efficacy (CSE), involving 174 US students aged 17–20 in a basic computer course. CSE is a particular application of Bandura’s more general self-efficacy construct (1977) in the field of computer

science and is commonly used as one’s judgment of his/her capability to use a computer. There is both a general and a more specific version of the CSE: General CSE (GCSE) refers to a person’s judgment of his/her ability to operate across multiple computer application domains; specific CSE refers to the individual’s effectiveness perception in performing specific computer tasks. This study considers that computer skills, current computer experience, and computer anxiety act as the main sources of information for an individual to judge his/her level of GCSE. Another source of information, such as verbal persuasion, is not included in the research model, since its influence in self-efficacy development is considered weak and vulnerable (Bandura 1977). The research results showed how female students had fewer computer skills and less computer experience than males. They also appeared to be more anxious in computer use and have lower levels of GCSE. The researchers argue that computer experiences and computer anxiety have mediated the effect of GCSE and suggest increasing the informatics experiences of girls, in order to help them develop greater security with computers.

There is also research that does not reveal differences in the sense of self-efficacy between males and females in middle school concerning computer science, such as the study conducted by Vekiri (2010). Vekiri involved 301 middle school students in Greece (grade 8 and 9) in order to examine self-efficacy beliefs among males and females in information technology and to inquire into how they perceive parent support and teacher expectations. Research found that perceived teacher expectations are positively associated with students’ beliefs about their computer skills. Unlike other studies, the results of this research did not reveal differences in males’ and females’ self-efficacy and value beliefs in ICT among middle school students. Instead, the study highlighted how their beliefs are differently influenced by parents and teachers. Specifically, perceived teacher expectations are more significant for the effectiveness of girls than boys, while the opposite is true regarding perceived parental support.

These results are confirmed also by de Weerd and Rommes (2012) who investigated the role of teachers in secondary school students' choices regarding science and technology. In particular, they revealed how teachers' attention perceived by females towards them are closely connected to their self-efficacy, a relation that does not exist among males, whose self-efficacy does not seem particularly influenced by teachers' attention.

Conclusion

The previous sections presented several research papers that investigate the role of gender difference in the sense of self-efficacy related to CT in K-12. Most of these papers show that girls, from primary school on up, tend to have lower self-efficacy than boys in technology, even if some investigations exist that state the opposite (see section "[Related Work: Computational Thinking, Gender Difference and Self-Efficacy in K-12](#)").

In general, it can be stated that gender differences in the sense of self-efficacy seem to start in primary school and continue in secondary school and into university. The diminished sense of self-efficacy among girls and women seems to be influenced by a complex set of beliefs about their experiences of CT in scholastic, family, and friendship circles (see section "[Self-Efficacy in Gender Difference](#)"). No comparison was possible among the variety of published research into self-efficacy (see section "[Related Work: Computational Thinking, Gender Difference and Self-Efficacy in K-12](#)"). That is because this work refers to students of different ages and nationalities, while some of it is focused on specific tasks and others look at more general aspects of CT.

In addition, the researchers use different scales to measure self-efficacy, indeed, very often they use questionnaires created ad hoc and validated internally (see section "[Introduction](#)").

To conclude, it is important to underline how research on self-efficacy in CT among K-12 students requires attending to factors that could contribute to producing distortion or even error

effects on analysis and interpretation of results. Pajares (2005) highlights four factors.

1. The first factor refers to achievements and previous practices, internal and external to the school context: if these variables are not checked, gender differences regarding academic beliefs could be "invalidated" (or better, nullified, Pajares 2005).
2. The second factor is the tendency of boys and girls to adopt different approaches when they respond to self-efficacy instruments. It is important to be cautious in reading and interpreting the results, as attention should not be limited to a mere statistical index. The reasons for this lie in the psychological development that characterizes the K-12 phase (but also beyond), which is different for males and females. In fact, adolescence for girls starts between 9 and 11 years while for boys between 11 and 13 years. Specifically, at this stage of life, several studies on girls and boys of the same age show that girls suffer from a decrease in self-efficacy in science (and some other subjects) compared to boys, and this gap increases as they age. Therefore, in interpreting the data, it is important to take into account the differences in development between males and females (mentioned above) and to hypothesize that because girls filter and process research questions more critically, they show a lower sense of security than their male colleagues.
3. The third factor to which to pay attention concerns the differences in average confidence levels reported by males and females. These variations are due to the variables of comparative judgments of self-efficacy based on beliefs not only in relation to the whole class or of the group of participants but also on the basis of the distinct sets of males and females. Therefore, it is important to include questions that take into account comparisons with classmates of the same gender and with the other gender. In this regard, Pajares (2005) points out that the analysis of gender differences, before coming to the conclusion that they actually exist, should know

how, for example, girls evaluate their self-efficacy not only with respect to the whole class group (or the whole group of participants) but also with respect to the separate groups of boys and girls. (This procedure is valid for both older and younger children.) Disaggregating data at this level helps to discriminate and better understand the beliefs of males and females.

4. The fourth factor that can affect gender differences in self-efficacy deals with stereotyped gender beliefs and is differentiated from the actual gender of the subject. The reference is to all those social, cultural, family, personal, and academic variables that can orient convictions about gender. From the Eccles (1987) studies, we learn that stereotypical gender differences seem to emerge and become influential during preadolescence and increase throughout adolescence. This happens first in girls and then in boys, due to the different ages at which they enter into puberty. These changes in the development phases depend on the maturation of the socialization processes, which become more and more sophisticated, as well as comparisons with “the others” (Eccles 1987); it is a period in which the role of gender is intensified, but so also are gender stereotypes held by adolescents. Eccles (1987) shows that there are a series of factors in the cultural milieu, including stereotypes of gender roles, that can play a decisive role in the commitment to certain disciplines compared to others in school and in future choices of university and career. Research shows that the more girls identify themselves in terms of female stereotypes of women’s occupations, the more likely they are to show attitudes of avoidance or rejection for scientific fields. There are studies that demonstrate that the influence of family, culture, and mass media is an important and at times crucial component in gender differences. For example, if parents consider science as a “male domain,” this can lower the motivation and interest of girls, as well as reduce their self-assurance in these areas. Research shows that many girls have an unjustifiably low sense of self-efficacy, despite having achieved tangible

results at school and demonstrated real potential. Even today, this potential cannot be prevented from being wasted. Society continues to lose talent that could contribute to the work, research, and development of the technology and scientific sectors.

Cross-References

- [Algorithmic Thinking in Primary Schools](#)
- [Computational Thinking](#)

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Gender Differences

► [Gender Differences in Computer Science Departments](#)

Gender Differences in Computer Science Departments

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Synonyms

[Computer science](#); [Computer science departments](#); [Gender differences](#); [Gender representation](#); [Performance](#); [Preferences](#)

Introduction

Women got involved with computer science (CS) literally from the moment of the creation of the scientific discipline and have passionately programmed computers for many decades. As far back as 1843, Ada Lovelace wrote programs on Charles Babbage's mechanical computer. In 1946, six women mathematicians, known also as human “computers” created working programs for the ENIAC computer during the Second World War. In the 1950s, the pioneering generation of CS featured a surprising number of prominent women who led research teams, defined computer languages, and even pioneered the history of CS. One of the first programmers, Grace Murray Hopper, played a key role in creating COBOL and standardizing FORTRAN, even named as the Data Processing Management Association's first “man of the year” in 1971 (Misa 2011).

In the 1960s, women entered the emerging CS profession in unusually big numbers. In 1970s, 22.5% of computer programmers were women

(Ensmenger 2011) while in mid-1980s women earned 37% of all US bachelor degrees in CS, and across these decades, women constituted about the 38% of the US “white-collar” CS workforce (such as systems analysts and software developers). Despite these early successes, in the late-1980s, women stop entering CS in big numbers, and the proportion of women studying CS actually began falling dramatically (Camp 2012).

Since then, the gender gap in CS has raised global concerns that gained more importance with the emerging Information Age. These concerns have motivated excessive research during the last decades, investigating the extent of the underrepresentation of women in CS education and workforce as well as addressing possible key factors affecting women’s participation in CS. The research identified several critical issues emerging from the unequal participation of males and females in CS, the most important of which are: (a) the huge demand that exists for people trained in CS, (b) the need for a diverse workforce to innovate high quality technologies, and (c) the goal of equal opportunity of both genders in the field.

Despite the widespread usage of computer technologies, only a small, unrepresentative sample of the population is involved in creating new technologies. In the USA, the overall need for computer scientists has severely outstripped the number of graduates entering the workforce, and it is estimated that only 17% of the 3.5 million CS-related jobs in the USA by 2026 will be filled by the US CS bachelor’s degree recipients. The great need of computer scientists is a reality for the EU as well. In particular, it is expected that 889,000 CS positions will be vacant in 2020 (Hüsing et al. 2013). However, women and other underrepresented groups are likely to bring great potential for filling these gaps both in the USA and the EU as gender diversity in CS workforce seems to improve productivity, creativity, innovation, and competitiveness. CS is a field created by innovative thinkers whose products and systems have become critical and have affected the daily lives of a broad section of the general population. Ideally, computer technologies should be developed by a population as diverse as its users. Increasing

the diversity of viewpoints in CS may help to ensure the design of new technologies that meet the needs of the diverse society.

However, the gender gap is not only an issue for CS but also for the rest Science, Technology, Engineering, and Math (STEM) fields. Gender differences in CS+STEM fields are reflected in the presence of females in CS+STEM tertiary education as well as males’ and females’ performance and preferences within these fields. Placing emphasis upon any gender differences in CS tertiary education, the aim of the present entry is to: (a) outline the gender representation in CS departments (depts), in terms of students, graduates, and faculty members, reporting results from a systematic analysis of data from a whole decade concerning all CS depts of an entire country (Greece) as well as comparisons of gender representation within CS+STEM fields, (b) to disclose the barriers that deter females from participating in CS, (c) to present performance issues in CS with an emphasis on the common stereotypes about females’ lack of abilities in CS, along with specific results from a study, conducted in Greece, regarding the curriculum of a CS dept so as to dispel the “myth” of gender differences in terms of performance, and finally (d) to discuss the effect of gender on course preferences in CS education supported by specific results emerged from a case study conducted in a specific CS dept in Greece.

Gender Representation in Computer Science Departments

CS has evolved from the discipline of math, but as electronic computers became accessible to the public, CS has started to be recognized as a valid discipline on its own. In the early 1960s, CS departments started to split themselves out from math departments and the first actual bachelor’s degree in computer science being awarded at Purdue in 1962. In fact, CS field grew rapidly from an esoteric field of study in the mid-1960s to a popular major by the mid-1980s, changing more rapidly than most STEM disciplines (Misa 2011).

Despite this fact, the number of females in CS has been falling since the mid-1980s, whereas

women continued to increase their representation in most of STEM disciplines. Specifically, the percentage of CS undergraduate degrees awarded to women in the USA had been decreasing since the mid-1980s from a high of 37.1% to a low of 17.8% in 2012 with a consistent descending trend (Camp 2012). This descending trend is unique in CS, as the proportion of undergraduate degrees awarded to women in all disciplines has increased the last decades reaching to a high of 57% in the USA in 2012, and the percentage of undergraduate degrees awarded to women in biological/life sciences, engineering, and physical sciences increased by 26.5%, 40.6%, and 47.8%, respectively (Camp 2012). More recent data show that while 57% of 2016 bachelor’s degree recipients in the USA were women, just 19% of CS bachelor’s degrees were awarded to females.

A clearer picture of the representation of women in CS in the USA – built by combining data sets from the National Science Foundation in the USA and longitudinal surveys – reveals that there are “*distinctive trajectories and dynamics*” at the undergraduate level compared to the graduate level (Hayes 2011). While women’s participation in the graduate level (master’s and doctoral degrees) is still low, there is a slight increase across the decades. It is at the undergraduate level, since the “turning point” in the mid-1980, in which the proportion of women earning CS degrees constantly declines. Compared to other STEM disciplines in which the proportion of women has been steadily increased, CS seems to be a field of extremes, being both the fastest growing and declining during different time periods concerning the representation of women (Hayes 2011).

The trend of female participation in the CS workforce follows a pattern similar to that in undergraduate CS education, especially for “white-collar” professions. The percentage of CS occupations in the US workforce held by women has been declining since 1991, when it reached a high of 36%, dropping to 26% in 2017. Despite the shrinking representation of females in CS undergraduate studies and workforce, the proportion of women at higher ranks, doctorates and faculty, have continued to grow overall (Hayes 2011).

To further clarify the gender representation picture drawn above, a specific example related to undergraduates’ (freshmen and graduates of bachelor’s degrees) and graduates’ (graduates of Master’s degrees and PhDs) representation in every Greek CS and Computer Engineering dept is presented below. In addition, an example illustrating results closely related to gender representation of faculty members in all Greek CS and Computer Engineering depts is also reported (Berdousis and Kordaki 2016).

Example of Gender Representation of Undergraduates and Graduates in CS Departments: The Greek Case

In this study, data regarding undergraduates and graduates from all Greek CS depts and Computer Engineering schools (“CS” – 14 CS University departments and 8 Electrical and Computer Engineering Schools) for a whole decade, 2002/2012, were quantitatively analyzed and compared to other STEM depts, namely: Biological Sciences and Environment (“Bio/Env”), Physical Sciences (“Phys”), Mathematics and Statistics (“Math”), and Engineering (“Eng”).

Table 1 demonstrates the total numbers (N) of male and female freshmen, graduates of undergraduate studies, graduates of master’s degrees and PhDs during the decade 2002–2012. The mean percentage of the female (%F) freshmen, graduates of undergraduate studies, graduates of master’s degrees and PhD are also presented in respect to all Greek Universities and Engineering Schools (“Overall”) and Greek CS depts and Computer Engineering schools (“CS”).

Gender Differences in Computer Science Departments, Table 1 Gender representation of students and graduates in Greek tertiary education 2002–2012: overall and CS

Undergraduate / graduate	Overall		CS	
	N	% F	N	% F
Freshmen	410,085	60.53	32,247	26.50
Graduates	313,332	64.33	17,798	29.54
Master	69,170	57.37	5933	34.45
PhD	15,666	38.78	2152	14.96

It seems that, “Overall,” more than 60% of the freshmen were females, nearly 65% of the bachelor degrees were awarded to women, whereas, almost 58% and 39% of master degrees and PhDs were earned by females, respectively.

As for “CS,” during the decade under study, about one out of four freshmen were females, while nearly 30% of the undergraduate degrees and almost 35% of the master degrees were awarded to females. The proportion of females who earned PhDs is even lower, down to approximately 15%. It is promising though that, despite the downward trend regarding the percentage of female freshmen throughout the decade, the percentage of female graduates is, on average, higher than the percentage of female freshmen while the percentage of female graduates of master’s degrees is higher than the respective number of female graduates of undergraduate studies (see Fig. 1). The upward trend in the percentages of female graduates of master’s degree programs in Greek CS depts over the last 7 years of the decade under study is another promising point. It verifies that a considerable percentage of women pursue and achieve a CS master’s degree after graduation. Additionally, as the decade progressed there was an observable increase in female graduates of PhDs. Eventually, the percentage of master’s degrees and PhDs

awarded to females appears a clear upward trend through the decade.

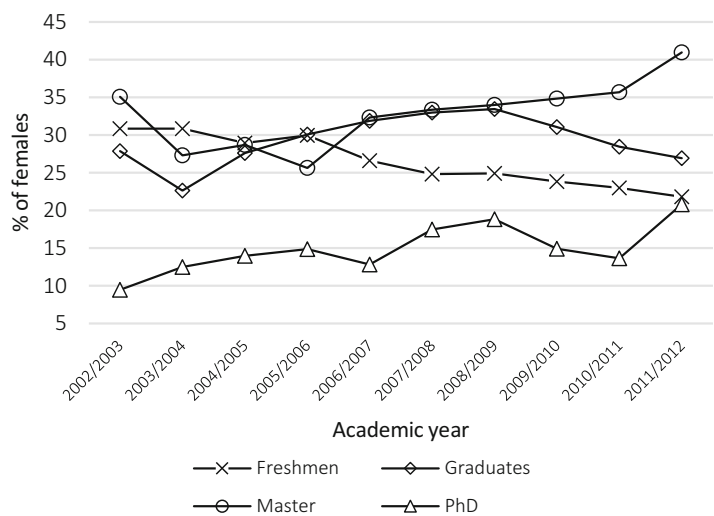
Comparing the presence of females in Greek CS depts with other STEM depts of the decade under study, in terms of freshmen, graduates, masters, and PhDs, it seems undoubtedly that females are worst represented in CS depts in all the aforementioned levels of study (see Fig. 2). Females in “Bio/Env” depts clearly outnumber males in every level of study, while in “Phys” depts, female are almost as many as males in terms of freshmen, and graduates of both undergraduate and graduate studies. Regarding “Math” depts, females approach the numbers of males, apart from PhD degrees where just one out of four graduates are females. Even in “Eng” depts, females constitute constantly over 30% of the freshmen and the graduates from undergraduate and graduate studies, leaving behind females in CS depts.

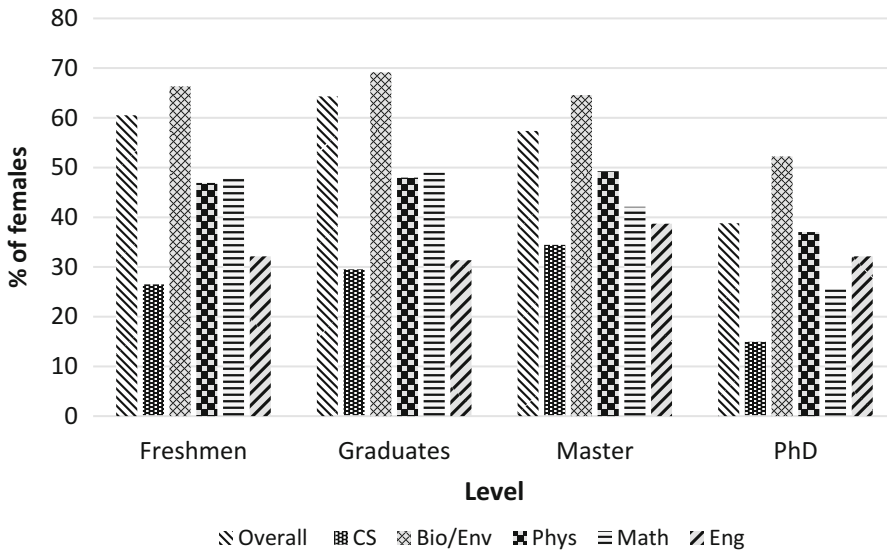
Example of Gender Representation of Faculty Members in CS Depts: The Greek Case

The presence of female faculty members in CS depts can play a crucial role in female-student retention in the field, as they demonstrate the presence, the participation, and the continuing prospects of women in CS. The positive role of a female role model in the retention of females in

Gender Differences in Computer Science Departments,

Fig. 1 Female students in CS depts in Greece: 2002–2012





Gender Differences in Computer Science Departments, Fig. 2 Females in CS+STEM depts in Greece: 2002–2012

CS highlights the need to investigate the presence of the female faculty, who could act as mentors/role models in CS depts. Taking CS depts in Greece as an example, data from the Hellenic Statistical Authority were exploited and a quantitative research was conducted to examine the gender representation of faculty members of all ranks (professors, associate professors, assistant professors, and lecturers) of CS+STEM depts in Greek tertiary education during the decade 2003–2013.

Table 2 presents the average number of faculty for each one of the four ranks in the aforementioned decade, and the percentage of females (%F), regarding all Greek Universities and Engineering Schools (“Overall”), as well as CS depts and Computer Engineering schools (“CS”).

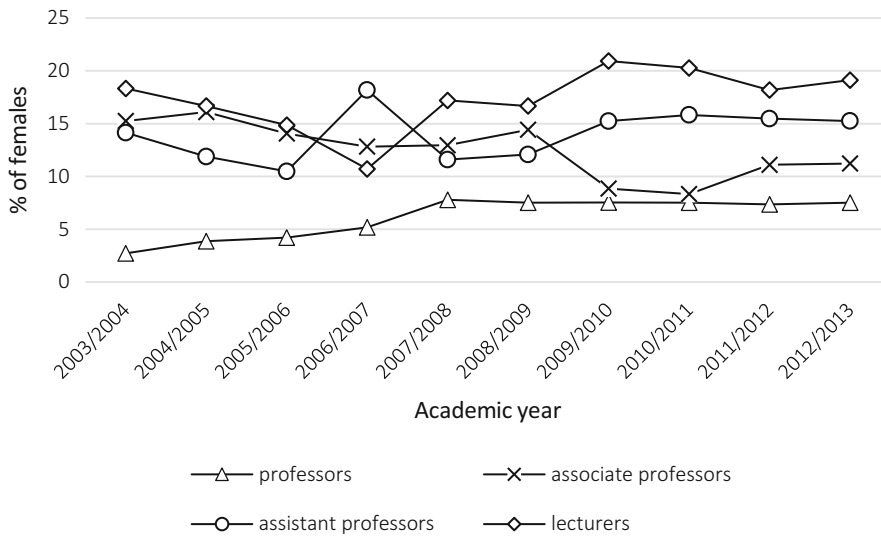
Regarding “Overall,” among the four ranks, females were better represented in the position of lecturers, followed by assistant professors, associate professors, and professors. This appears to be the case for CS depts as well. It appears that female faculty in CS depts was better represented as we move down towards the lower ranks.

Focusing on the CS depts and the fluctuation of the percentage of females in each of the four

Gender Differences in Computer Science Departments, Table 2 Gender representation of faculty members in Greek Tertiary Education, 2003–2013: overall and CS

Faculty members	Overall		CS	
	Average number of the decade	% F	Average number of the decade	% F
Professors	2551	18.15	224	6.34
Associate professors	2050	28.52	113	12.54
Assistant professors	2589	33.57	140	14.20
Lecturers	1691	39.38	76	17.21

ranks throughout the decade, noteworthy trends are revealed (Fig. 3). The percentage of female professors appears to be the lowest among ranks for each year of the decade, varying from almost 3% to 8%, with a slight upward trend in the first years of the decade. The percentage of female associate professors in CS depts varied from about 8% to 16%, following a downward trend



Gender Differences in Computer Science Departments, Fig. 3 Female faculty members in CS depts in Greece: 2003–2013

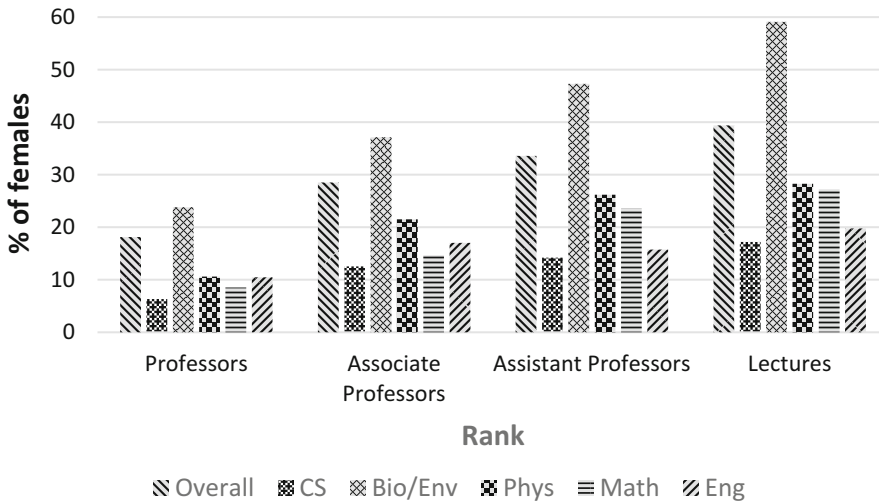
throughout the decade. The percentage of female assistant professors varied from 12% to 18%, decreasing in the first 2 years of the decade, fluctuated for the following 3 years and remained at around 15% in the last 4 years of the decade. The downward trend in the first years of the decade appears to be true for female lecturers as well. Their percentage varied from almost 11% to 21%, with a clear upward trend in the last years of the decade. Bearing in mind the upward trend regarding the percentage of PhD degrees awarded to females, the presence of females in academia is probably an expected advancement.

Comparing the female representation, regarding faculty members, in CS depts with the rest of the STEM fields, it is apparent that the percentages of female faculty in CS depts were the lowest among all STEM disciplines in every rank (Fig. 4). Females were better represented, in every rank, in “Bio/Env” departments, while their percentages in “Phys” depts were the second highest. Interestingly, females in CS+STEM fields seem to be better represented as we move down the ranks. Yet, the upward trends regarding the presence of females in academia, even though it mainly concerns lectures, along with the ascending trend

in PhD degrees awarded to females, seem to be encouraging and promising for a better representation of females in the future.

Barriers That Deter Females from Participating in Computer Science

An explanation for female underrepresentation in CS education given by Abbate (2011) assumes that, as college students flocked to CS in the mid-1980s, depts tried to cut down the numbers to a manageable size. Thus, many depts instituted entry requirements that favored candidates with prior computer experience, discouraging those students who had less experience or confidence. As a result, fewer women than men had been admitted to CS. The gendered effects of these changes were probably unintentional, but true. Hayes (2011) provides another explanation, arguing that as the discipline of CS became established and known to the general public during the 1970s and 1980s, unappealing stereotypes of computer scientists as “computer nerds” and “hackers” also became well-known in the general consciousness. The increasing prevalence of these stereotypes from the 1980s through the present day may have contributed to a decline in the proportion of



Gender Differences in Computer Science Departments, Fig. 4 Female faculty members in Greek CS+STEM depts: 2003–2013

women choosing CS. These stereotypes were probably unappealing to both men and women but disproportionately to women. What is more, as CS professionalized, CS programs were settled in different depts, such as mathematics, physics, and electrical engineering and accommodated in a variety of colleges ranging from liberal arts to physical sciences and engineering. Progressively, these programs became independent CS depts, mainly located in engineering colleges. In this way, CS started out with a wide variety of disciplinary cultural influences, and it has gradually moved closer to a culture of the “male-dominant” engineering.

The reasons for the underrepresentation of women in CS have been an issue of interest for many decades. Research, over time, has identified several key social and structural factors that influence females’ participation in CS, often deterring them from choosing future CS education or careers in CS (Gürer and Camp 2002; Barker and Aspray 2006; Ashcraft et al. 2012). Females’ perceptions, interest, confidence, attitudes, and career decisions are shaped by the larger environment they learn about the field of CS preventing them from being able to make a truly free choice. In that sense, education, family and teacher

support, computing experience, and stereotypes seem to be crucial factors.

Regarding education, irrelevant curriculum with no connection to real life, teaching practices that discourage collaboration and teachers with (un)conscious bias about girls’ abilities, and the culture of the field may deter girls, even boys, from pursuing CS. The uncomfortable, unwelcome environment in a CS class dominated by boys reinforces the loss of girls’ interest. Families, also, can play a significant role in girls’ and boys’ decision about studying CS. The parental support and encouragement have a decidedly powerful impact on girls’ choices, while the early exposure to both computers and computing at home as well as the kind of computing experience seems to be key factors. Another obstacle seems to be the lack of female role models in CS. It has been proved that the existence of females in the field – teachers, faculty, and colleagues – can inspire women, improve their self-efficacy, and reverse negative stereotypes as they can realize, through real-life examples that they can pursue, persist and succeed in CS. The perceived similarity with successful women in the field, and the feeling that they “fit in” could be a crucial factor in pursuing CS (Gürer and Camp 2002).

Most recent studies also contend that one novel and powerful social factor that may perpetuate the underrepresentation of women in CS is the *stereotypes* about the culture of the field, which in some cases act as “educational gatekeepers,” discouraging females from entering CS (Cheryan et al. 2015). The image of a computer scientist is one of a genius male computer hacker who spends a great deal of time alone on the computer, has an inadequate social life, and enjoys hobbies involving science fiction. These stereotypes are dominant in our society and students tend to espouse them. Those girls, even boys, therefore, who feel out of that culture, abandon the idea of pursuing CS.

Gender Differences in Performance in Computer Science Education

Beyond the stereotypes about the culture of CS, females face negative stereotypes about their abilities, making them feel like they do not fit well in the CS field. These negative stereotypes are based on some socially constructed “myths” about gender differences in cognitive skills and academic ability. These “myths” are not real in a scientific and empirical sense regarding actual measures of ability and intelligence, but they are real, as they have real social implications; they constitute obstacles discouraging females. Even though there are no gender differences in cognitive skills and ability, people still believe in and behave in response to the belief of such gender differences, and consequently, a large gender disparity persists in higher education and careers in the CS+STEM fields.

Evidence from the STEM fields indicates that there are no significant differences in performance between males and females, with males to perform slightly better on the construct of science and have more self-efficacy (Kiran and Sungur 2012). The fact that the gender gap in measurements of STEM ability and achievements has narrowed and nearly disappeared has been mentioned since 1990 (Mickelson 1989). The ability and intelligence of males and females in science subjects showed little to no difference (Mickelson 1989), while, especially in math performance, gender differences were small, and in some

cases, females outperformed males but only by a negligible amount (Hyde et al. 2008). Later studies emphasized on the performance of males and females in STEM in high school, and specifically, on the tools that school uses to measure science achievements: grades and test scores. Even though males and females were similar in achievement, females had higher final grades in STEM while males had higher test scores (Britner 2008). In a review of 25 years of evidence, Jacobs (2005) maintained that differences in grades is generally weak and concluded that females have achieved increasing success in STEM courses, closing the gender gap, while a later study showed that no significant gender differences were found on five science academic outcomes (Matthews et al. 2009). Some evidence from CS also suggests that male and female students seem to perform equally well in CS courses (Ilias and Kordaki 2006).

Nevertheless, when different subject domains are taken into consideration, females perform better than males on the social aspects of science factors, while males tend to perform better than females on the constructs of science factors (Kiran and Sungur 2012). Upon closer inspection within the STEM fields, differences emerge in terms of which discipline males and females follow in education and career (Amelink 2009).

There is some evidence demonstrating that performance is closely related to the domain-specific self-competence, self-efficacy beliefs and motivation, which are affected by the above-mentioned negative stereotypes (Jacobs et al. 2002). Actually, those students who believe that they have the ability to accomplish a particular task perform better and are more motivated to select increasingly challenging tasks (Ibid). In fact, expectancies of success (such as self-efficacy) are critical issues in educational and career choices. Thus, computer self-efficacy predicts involvement with computers and intention to take CS courses (Sáinz and Eccles 2012). The more appropriate a subject is considered for males, the lower is females’ self-efficacy (Correll 2004). Females tend to have low self-efficacy and believe they have little natural ability in male-dominated domains, including mathematics,

engineering, and CS. In particular, females' self-efficacy is low when compared to their actual abilities, skills, or performance (Correll 2004). Beyer (2014) found evidence for actual gender differences in computer self-efficacy, stereotypes, interests, and values. Increasing females' computing self-efficacy would positively affect their representation in CS. Regarding especially CS, research suggests that computer self-efficacy is also influenced by computer experience (He and Freeman 2010) and previous performance (Correll 2004).

In order to provide a deeper understanding about the gender gap in the performance in CS education, a study investigating gender differences in terms of performance in the entire curriculum of a CS department is presented below.

Example of Gender Differences in Performance: The Case of a Greek CS Dept

In this study, data from a Greek CS dept were analyzed in order to explore gender differences in graduates' performance in CS courses (Berdousis and Kordaki 2019). Specifically, 89 degrees covering a 6-year period of graduation at the Department of Computer Science and Technology (DCS&T), University of Peloponnese, Greece, were studied. This study has taken into consideration the degrees of all graduate students who enrolled from 2002 to 2008. The number of male graduates was 69 (77,53%), and the number of female graduates was 20 (22,47%). These percentages of male and female graduates are in line with a relevant research about the representative percentages of CS graduates from CS depts in Greece (Kordaki and Berdousis 2017).

According to the curriculum of DCS&T, in that academic period, students had to enroll in 21 compulsory courses as well as in 25 electives and successfully fulfill the appropriate requirements in order to award a degree. According to the curriculum, courses were classified into three divisions, namely: "Theoretical Computer Science" (TCS), "Software Systems" (SS), and "Computer Technology and Computer Systems" (CTCS). TCS had 3 compulsory and 10 elective theoretical CS courses, SS had 8 compulsory

and 29 elective software engineering courses, and CTCS had 3 compulsory and 15 elective hardware-oriented courses. There were also 2 groups of courses: "Math and Physics" (M&P) consisted by 7 compulsory courses related to Mathematics and Physics, and "General Education" (GE) that included 21 elective courses regarding social, ethical, law, and humanities issues. The data regarding the 89 graduates were collected from the official records of the DCS&T without any reference to the personal data of the graduates apart from their gender. Those data referred to the gender of each graduate, the courses that she/he had passed along with her/his grades. For each one of the 100 available compulsory/elective courses, mean grades and standard deviation values for males and females were calculated and independent sample t-tests were conducted to compare the mean grades of male and female graduates.

The analysis revealed few statistically significant differences in performance, and specifically in ten CS courses, between male and female graduates. It seems that males performed better than females in seven courses and females better than males in three courses (Table 3). Interestingly, males performed significantly better than females in four courses from the SS division, as well as in two compulsory Math courses and one course from GE division. Females, on the other hand, performed significantly better in Human-Computer Interaction, and one elective from the CTCS and GE divisions correspondingly. In that sense, the findings from this CS dept in Greece are in line with relevant studies in CS+STEM (Ding et al. 2006; Ilias and Kordaki 2006; Kiran and Sungur 2012; Alkhadrawi 2015), which support that there are no major differences in performance between males and females, and that, when different domains (in this case, divisions) are taken into account, males tend to perform better than females on the constructs of science factors, in case of CS; math and programming, whereas females perform better than males in the social aspects and the use of computer technology, such as interfaces between people and computers (Human-Computer Interaction).

Gender Differences in Computer Science Departments, Table 3 Gender differences in graduates' performance

Statistically significant differences between males' and females' performance in CS courses (per division)								
Division	Courses	Group statistics				Independent samples test – T test for equality of means		
		Male		Female		t	Sig. (2-tailed)	Mean difference (I-J)
		Mean grade (I)	SD	Mean grade (J)	SD			
Software Systems	Computer Programming, I	7.31	1.62	6.15	0.99	3.964	0.000	1.17**
	Human-Computer Interaction	6.75	1.24	7.35	1.85	−1.869	0.045	−0.60*
	Info management on the Internet	8.6	1.11	7	1.87	2.102	0.030	1.60*
	Advanced topics in Soft. Systems	9.17	0.80	8.29	1.11	2.428	0.021	0.88*
	Systems security	8.41	1.32	7	1.56	2.345	0.023	1.41*
Computer Technology and Computer Systems	Information theory and coding	5.65	0.95	6.69	1.46	−2.148	0.042	−1.04*
Mathematics and Physics	Linear Algebra	6.44	1.31	5.55	1.06	2.782	0.007	0.89*
	Mathematics I	6.59	1.43	5.98	1.27	1.728	0.048	0.61*
General Education	Social and Professional Issues	8.46	1.20	5.8	1.10	4.310	0.001	2.66*
	Differential Equation	7.31	1.91	8.67	1.78	−1.987	0.047	−1.36*

*The difference is significant at the 0.05 level

**The difference is significant at the 0.01 level

Gender Differences in Preferences in Computer Science Education

To this point, it seems that females do not participate in CS+STEM education as much as males, yet when they do, they perform equally well. Beyond the different preferences of females in terms of specific subject domains, differences in course preferences within each subject domain are also evident. Course selections within STEM fields reveal certain persistent differences in preferences regarding STEM (Alkhadrawi 2015). Even when the overall number of males and females in science majors is nearly equal, the specific field within science still differs significantly: males select high-level mathematics, engineering, CS, and physical sciences in higher numbers, while more females choose biology and

chemistry (Amelink 2009). It appears that males attach a higher value and utility to math and have higher self-concept in math, engaging in the math field more frequently than females (Van de Gaer et al. 2008).

As for the reasons which shape these preferences, it seems that self-efficacy in CS+STEM is an important one which affects not only students' choice of courses but also their decision to select a major in these fields (Beyer 2014). Additional factors, such as interest in CS, computer confidence, conscientiousness, and openness to experiences have been acknowledged as significant predictors of taking CS courses (Beyer 2014).

Focusing solely on CS, a study investigating the course choices of male and female students from the entire curriculum of a CS department

would uncover gender differences in terms of course preferences. The following second phase of the example of the Greek CS dept will discuss these preferences of CS courses of male and female graduates.

Example of Gender Differences in Preferences: The Case of a Greek CS Dept

Along with the differences in the performance of males and females in CS courses, the study of the degrees from the DCS&T in Greece revealed gender differences in course preferences (Berdousis and Kordaki 2019). Table 4 depicts the CS elective courses from which it is evident that there are statistically significant differences in course preferences between males and females.

The data analysis revealed that males selected at a higher percentage, compared to females, two elective courses related to computer architecture from the CTCS division (Computer organization), and advanced topics of Software Systems from the SS division (Advanced User Interfaces, VR). GE electives were not popular among male students, compared to females. The above-mentioned course selections of male students enrich the findings of relevant studies in STEM fields which support that males take engineering and advanced CS courses in higher percentages compared to females (Bussey and Bandura 1999; Amelink 2009).

On the contrary, females selected at statistically significantly higher percentages than males eight electives: three of them are related to the Theoretical Computer Science division (Computational Geometry, Fractals, and Cryptography) as well as three courses related to humanities and social sciences from the GE division (pedagogy, sociology, and cognitive science). These selections of females enhance the findings of other relevant studies in CS which explain that females prefer theoretical computer science issues as well as the social aspects of CS and the solutions of community problems over computing for the sake of computing (Margolis et al. 2000). They seek to interact with people rather than things, desire to be helpful to others or society, and pursue to combine career and family (Beyer 2014) in a “balanced” life with multiple roles and goals (Eccles 2007).

It is a fact that there are differences in the selection of CS courses between male and female students in CS education. These differences in preferences may reflect stereotypical views about the role of males and females in CS, different personality characteristics and self-efficacy beliefs (Beyer 2014), as well as diverse values and interests of males and females. Males prefer courses focusing on the core of CS, while females prefer courses oriented towards theoretical issues as well as seeking to

Gender Differences in Computer Science Departments, Table 4 Gender differences in graduates’ preferences

Statistically significant differences in the course preferences of male and female graduates						
Division	Courses	Graduates who selected the course (%)		Chi-square test		
		Male	Female	Chi-square	df	Asymp. sig
Theoretical Computer Science	Computational Geometry	36.23	60	3.606	1	0.048
	Fractals	27.54	35	3.562	1	0.049
	Cryptography	14.49	40	6.253	1	0.012
Software Systems	Advanced User Interfaces, VR	62.32	35	4.701	1	0.030
	Machine learning and data mining	21.74	45	4.260	1	0.039
Computer Technology and Computer Systems	Hardware Description Languages II	14.49	30	11.221	1	0.001
	Computer organization	91.30	70	6.033	1	0.014
General Education	Pedagogy	68.12	90	3.771	1	0.048
	Sociology	27.54	50	3.662	1	0.049
	Cognitive Science	11.59	25	14.175	1	0.001

be useful to others pursuing interaction with people (Beyer and Haller 2006).

Summary

Over the last years, gender gap in CS+STEM education is an issue that has raised global concerns. Female representation in CS+STEM secondary and higher education and gender differences in performance and preferences within these fields are research topics that merit attention. Focusing on CS higher education, the present entry attempted to portrait gender differences in CS depts by: (a) outlying the gender representation in CS depts, (b) discussing the obstacles that deter females from participating in CS, (c) deliberating performance issues in CS, and (d) analyzing the effect of gender on students' preferences in CS depts. Regarding students, graduates, and faculty representation in CS depts, the results from a systematic analysis of data from a whole decade concerning all CS depts of Greece were also presented, whereas, differences in performance and preferences were also discussed on the basis of a study conducted in Greece concerning the whole curriculum of a CS dept.

In spite of the remarkable presence of females in CS the first years of its establishment as a scientific field, the number of females in CS has been falling since the mid-1980s, while women continued to increase their representation in most of STEM disciplines. Especially in CS higher education, it seems that females are constantly underrepresented in undergraduate and graduate studies, with a downward trend regarding freshmen. It is promising though that, there has been an upward trend in the percentage of the master degrees and PhDs' awarded to females the last years. Despite this encouraging trend in graduate studies, it was clear that the percentages of females in CS depts regarding undergraduate and graduate studies were the lowest compared to other STEM fields. The recruitment and the retention of females in CS+STEM depts, among other factors, seem to be influenced by the presence of female faculty members in these depts. Unfortunately, females faculty members

in CS+STEM depts are the minority, and, as the aforementioned study in Greece indicated, among the four ranks (professors, associate professors, assistant professors and lecturers), females are better represented in the lowest position, that of lecturers. Things for CS depts appear to be even worse, as the percentages of female faculty in those depts were the lowest among all STEM disciplines in every rank. Taking the above into consideration, it seems that females are clearly underrepresented in CS depts. The reasons for this underrepresentation are complex and multilayered. Females' perceptions, interest, confidence, attitudes, and career decisions are formed by the larger environment they learn about the field of CS. Especially, negative stereotypes about the culture of the field prevent females from entering CS as they fell out of the culture, while stereotypes about their capabilities in CS create a "myth" about gender differences in cognitive skills and academic ability, enlarging the gender disparity in higher education. Reinforcing the results of relevant research in STEM fields, the study conducted in Greece, regarding students' performance in the CS courses of the whole curriculum of a CS dept showed that there were not major differences in performance between males and females, and that, when different domains are taken into account, males tend to perform better than females in math and programming, and females better than males in courses related to interfaces between people and computers. This study also discovered gender differences in course selection within CS domain, revealing that while males take engineering and advanced CS courses in higher percentages, females prefer courses oriented towards theoretical issues as well as courses related to the social aspects of CS.

Cross-References

- ▶ [Teaching and Learning Computational Thinking and Coding Skills](#)
- ▶ [Underrepresentation of Girls in Computing](#)
- ▶ [Value of Teaching Computer Science](#)
- ▶ [Why Teach History of Computing?](#)

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Human, Social, and Ethical Aspects of Information Technology Management Systems

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Synonyms

[Anthropocentric aspects of IT management systems](#); [Humanistic aspects of IT management systems](#)

Definition

There are innumerable definitions that have been proposed regarding the concept of ethics throughout the ages. One of the simplest and most general, while at the same time most illuminating, defines ethics as a set of moral principles that drive the behavior of a person. By implication of this definition, ethics are not fixed, since the moral principles of both individuals and societies can be changing, even volatile. There is a strong philosophical and ethical tradition in Western countries coming from the ancient Greek schools

of thought. This tradition, although important in the West, cannot eclipse other philosophical and ethical traditions, for example, the Chinese and Indian traditions; and since no one can be considered superior to another, it is necessary to construct an ethical paradigm based on the diverse cultural currents and historical traditions of the world. Said paradigm would have as its main advantage its integrating character, although one cannot ignore the complexity inherent in the attempt to reach a universally accepted agreement on what behavior is ethical or not (Gammack and Goulding 1999).

Introduction

Information technologies (IT) are instruments that make it possible to streamline the processes of capturing, organizing, combining, using, storing, and disseminating information. As such, they use a material – information – which, although intangible, has a relevance that can be significant because of its influence on goods and people through the decisions made using it. Since the large-scale development of computers and information technologies in general, an important role has been given to technological factors and those related to the development of methodologies that help ensure the success of information systems. This vision was logical due to the high cost of technological infrastructures and the personnel in charge, which constituted a strong condition for those responsible for information systems and technologies. Over the years, the great development that information technology has experienced has led to the economic factor being moved increasingly toward the background and other factors, previously barely considered, gaining prominence (Cederberg and Valenza 2012). Some of these factors are related to the human sphere and have to do with personal, social, and ethical issues. In the following sections, considerations will be made on these issues and how they can affect the work of educational management teams in terms of their decisions regarding the IT infrastructure in their charge.

Ethics and IT

It is not easy to find a balance between the protection of information of a personal nature and the right of the rest of society to know information that may be of public interest (privacy vs. freedom of information). This dilemma becomes even more difficult considering that we are immersed in an information-intensive society of a multicultural nature, which is, therefore, continuously growing in complexity (Hagen 2009). It could be argued that the ethical aspects present in the management of educational IT, since the field of ethics is dynamic and continuously evolving, integrating different perspectives and cultures, are nothing but a mirror of the times, marked by a continuous cultural and economic globalization.

Having the ability to collect, process, store, and use information gives a form of power to educational managers. For this reason, educational managers must be aware that this power has an associated level of responsibility and that its objective is to use the available information to offer a set of services that allows the stakeholders of the education system (students, teachers, administrators, parents, and society in general) to work more efficiently or improves the quality of their lives.

At this point, it is pertinent to distinguish between aspects related to the assurance over privacy of information, for which procedures have been developed under laws in many countries, and others that have to do with decisions of an ethical nature. The first group can include questions such as who should have access and to what information; how to protect individual privacy; what should be considered as information belonging to the education center; what information to offer to other educational entities and to society in general; or how long to maintain the storage of electronic records, to give some examples. For this purpose, laws such as the EU directive on the processing of personal data (European Union 1995) and the US Health Insurance Portability and Accountability Act (1996) have been promulgated. On the other hand, other aspects also intervene, fundamentally of a social and

human nature, on which it is more difficult to legislate, but which have great importance due to their influence on people and societies. In order to cope this broad spectrum of situations, some codes of ethics have been developed by numerous prestigious institutions. These codes do not only focus on aspects related to the privacy of information, which, as has been mentioned, is an issue widely accounted for in numerous national laws. The following can be mentioned in this group: (i) Ethics Code of the American Society for Information Science, (ii) American Library Association, and (iii) International Center for Information Ethics (ICIE).

Technology has an impact on society as a catalyst for innovation. IT, which is possibly the fastest developing form of technology in the history of mankind, has impacted all societies across the globe. This impact, which is not only economic but also of social type, is not alien to any kind of ethical interpretation. At the educational field, at times, it is difficult to elucidate at precisely what moment the managerial teams of education centers should intervene to avoid any damaging effects on individuals and on society, as a whole, that could result from an unethical use of IT at education centers.

Effect of IT on Work and Work Strategies

IT, from its inception, has had a double influence on the generation of employment. The need to provide organizations with competent people to implement and maintain complex computer systems, both in terms of hardware and software, has generated a requirement for specialized personnel and, from the beginning, the impulse to create new studies, both vocational and superior, aimed at training a new type of professional. It can be said that the rise of studies related directly or indirectly to IT (information technology, electronics, telecommunications, materials physics, etc.) has influenced and, at the same time, has been influenced by the development of IT. These are professional careers that either did not exist or existed with relatively little importance (as in the case of telecommunications engineering) just

a century ago. Today, such occupations are considered a fundamental part of the professional sphere and constitute a significant number of the courses on offer both in terms of vocational training and in higher education. The individual trained in these professions continues to enjoy favorable expectations of professional integration, given that the new manifestations of IT (social networks, artificial intelligence, cybernetics) also demand new professionals, and it is highly likely that the demand for this type of professional will continue to increase for the foreseeable future (Mardis et al. 2017).

However, parallel to the development of IT and its favorable implications for job creation, it has also helped to give rise to, on the contrary, a phenomenon of job loss (Trusson and Woods 2017). This is due to the increasing automatization of tasks that can be carried out more efficiently by automated systems. A job loss also may occur in those occupations that IT can support in such a way that a smaller volume of human labor is necessary. This is the case, for example, for workers on assembly lines, accountants, and in areas of the administrative field, among many others. This double implication of IT has been debated for a long time, and experience seems to point to the need for continuous adaptation of professionals to the new environments developed by IT, through training and professional retraining. The most pessimistic consider this phenomenon a steady and inevitable replacement of people by machines, while the most optimistic consider it an opportunity for people to do more creative and stimulating work, leaving repetitive, monotonous and mundane work for the machines.

In the field of education, where IT has also burst in through the door, there has not been a significant, negative effect on the level of employment for human beings. For educational managers, traditionally, the priority has been to use IT as a tool for improving the teaching-learning process, enhancing the teacher's role in the classroom rather than usurping it, which has meant that, in this particular area at least, there has been no substitution of human beings for machines. On the other hand, given that the administration of education centers, except the most complex ones, such as universities, has

not traditionally included a strong human component for the accomplishment of administrative tasks, there has not been a dramatic change in the level of employment in these positions either at schools or education centers in general. The administration staff of these centers, from the smallest to the largest, use IT as a support tool, although it is still necessary for them to perform functions analogous to those that were done before the inclusion of the IT in processes pertaining to the administrative duties of education centers. However, educational managers should consider in their future agenda the possibility that IT will significantly affect the number of teachers in their centers. The development of teaching materials by companies and organizations specializing in education and massive online training systems, among others, may lead to the choice of using these resources, compelling teachers to acquire a lesser role in the formative process and reducing their numbers overall.

Another aspect related to the possible negative influence of IT in the workplace may spring from its tendency to break down the boundaries between home and work-life. The availability of electronic devices that, via different types of networks, allow contact with the office, both by voice and by data, is increasingly resulting in the home becoming an extension of the workplace. This subtracts from time that belongs to the individual and that should be regarded as personal. Often, managers make use of mobile phones, e-mail, or messaging apps to contact employees or colleagues regarding work issues during non-office hours. On the other hand, the workload, insofar as meeting objectives and deadlines, can be so demanding that it gives rise to the need to continue working at home, creating the paradox that it is the employee who shoulders the expense of contracting, and paying for the services of, service providers who ensure the quick access to the network that makes the home a more efficient workplace.

In the field of education, it is relatively easy for this circumstance to occur due to the fractional nature of the work. Of the professional group with the greatest presence in education, teachers, it is usual for a large portion of their activities to be carried out outside of the workplace, for

example, preparation of classes, correction of tests and exams, preparation of teaching materials, etc. Educational managers may encounter the counter-productive situation that even if they intend to avoid practices that lead to teachers working outside of their place of employment or work schedule, they actually promote this situation with their decisions. The creation of virtual electronic work spaces (online repositories of teaching materials, tracking and management of student activity systems, online administrative systems, etc.) can lead to the continued use of IT from the homes of the teachers. In this case, it is difficult to establish any kind of recommendation. The incorporation of this type of electronic virtual environment has become a practical necessity at all levels of education and trying to prevent or reduce its use outside of the hours or place of work could impede one of its main advantages, which is its ubiquity and the possibility of access from any place and at any time. In any case, like practically all ethical aspects related to IT, it should constitute an element of collective reflection on the part of the staff of education centers. In this way, if it is necessary to develop some kind of ethical code in this regard, it should be the result of collective reflection and commitment.

Environmental Considerations

The environment poses a question that has been incorporated relatively recently into the set of social and ethical variables related to the use of IT. Concern for the environment has meant that aspects which, in the past, went unnoticed are taken into account, such as the energy consumption of electronic devices, the life cycle that has ultimately led to the manufacture of each device with its environmental cost, and, finally, the influence on the environment once devices are discarded and become waste materials. The first of the issues is related to the consumption of electricity that keeps the IT infrastructure in operation, both in terms of the equipment itself and the facilities in which they are used (light, air conditioners, etc.). This issue must be addressed by educational management teams in an active way, providing facilities with systems that ensure

the effective shutdown of equipment and utilities when not being used, as well as promoting the awareness of users regarding energy expenditure. In this sense, it could be very useful to inform users about the link between the savings in electricity with a lower level of the emission of CO₂ and other greenhouse gases (Bekaroo et al. 2012).

Another important environmental aspect is the knowledge of the manufacturing life cycle of the electronic device. The manufacturing life cycle reflects the environmental cost of developing a particular device. The life cycle, in the case of computers, quantify the use of minerals, plastics obtained from fossil fuels, the consumption of manufacturing facilities, the transport of raw materials and manufactured products, etc. All these inputs are summed up to obtain a value that indicates, either in the form of spent energy or generation of polluting substances, the negative effect that the manufacture of electronic components has on the environment. The environmental costs could be reflected in a “green label,” which would complement the information regarding the sale price of the product and which, along with the price, serves as a guide to making purchasing decisions. In the case of education centers, which usually carry out purchases of computers and other electronic equipment in bulk, it could contribute greatly toward environmental awareness if all stakeholders were informed about the ecological footprint left by the manufacturing life cycle of devices so that an appropriate purchasing policy could then be followed. This policy would not grant the highest purchase priority to the price or to other variables, such as the availability of technical support services, but to a new, environmentally sensitive variable. Certainly, this policy could imply extra economic cost in the purchase of equipment, although it could be justified before the education authorities for the environmental benefits that it would entail. In addition, acting as pioneers with this type of initiative and, above all, communicating it to other stakeholders may send a powerful message that could be copied and replicated by the families of the students in their purchases of electronic devices.

Related to the environment is the issue of outdated or obsolete electronic equipment becoming waste. Concerns are often raised over the

lack of environmental responsibility that sees electronic waste products ending up being deposited along with regular household rubbish in landfill sites. This irresponsible action is detrimental because electronic devices can include mineral components that are harmful to the environment (mercury, lead, etc.), so these must either be deposited at an approved recycling center or else selective collection of waste must be carried out that ensures its shipment to the appropriate centers for dealing with these materials and substances. Certainly, at the level of the educational center, the responsibility of its management teams ends when the discarded equipment is deposited in an approved center for recycling or selective collection, but it should not be forgotten that there should be some form of assurance by the competent authorities that the recycling facilities comply with the parameters established for this type of center (Agarwal and Nath 2011). It has been detected that, in the past, some of these companies have diverted waste to developing countries, where they are abandoned without any recycling process occurring. In this sense, an initiative of the educational management could be to prolong the working life of these devices. Sometimes, a plan to update equipment, based mainly on increasing the capacity of some of the components of the motherboards of computers (RAM, processors) or their hard drives, is enough to prolong for a significant time the use of computers, depending on their intended use at the educational center. On other occasions, when they have definitively reached the end of their life span according to their purpose within the educational center, their usefulness can be extended by transferring them to institutions or organizations whose users require less computing power and can take advantage of them for other uses.

Health and IT

Concern over health has brought with it an interest in working conditions due to the circumstances in which people interact with the physical elements that surround them, which have been designed precisely to help carry out their

work. Working for a long time with physical and technological devices and instruments can adversely affect health. This detrimental effect on health can be translated into the occurrence of illnesses and diseases that, in the end, mean a reduction in the effectiveness and efficiency of the worker. Therefore, it is neither beneficial to the worker nor to the organization in which the work is carried out. In identifying the negative effects on health and on the productivity in general, there has been growing concern for the improvement of the conditions of interaction between individuals and the devices they use, leading to the development of a scientific discipline called ergonomics. The goal of ergonomics is to understand the interactions between humans and the physical elements that surround them, based on theories, development of work methods, and designs aimed at optimizing health and improving results at work. IT, being another form of technology, can lead to injuries and health problems caused by prolonged use. For this reason, those responsible for the management of IT infrastructure must take this matter into consideration in order to ensure the health of staff (Ahmed and Shaukat 2018).

Specifically, the continued use of IT can lead to physical ailments such as headaches, blurred vision, backaches, fatigue, eyestrain, wrist and finger pain, and repetitive stress injuries (Nicolakakis et al. 2017; Andersen et al. 2011). Based on the ergonomic proposals that have been developed to reduce the likelihood of the manifestation of these ailments, educational managers must promote healthy habits as part of the work routine. It is recommended to receive advice from healthcare institutions, as well as from the educational administration itself about the location and disposition of physical equipment and optimal working conditions (light, ventilation, correct positions to take up at the computer or while using other devices, etc.). These recommendations must be communicated to the user so that they are aware of the importance of following a pattern of healthy behavior regarding the use of electronic devices, and so they adopt all those measures that, in the end, will result in their own good health.

There is another, more subtle consequence of IT use that can affect health, which is hard to warn of and difficult to avoid, known as “technostress.” It is a state induced by heavy use of electronic devices that can generate impatience, frustration and a special kind of sensitivity, and even hostility, toward other people. The possible root cause of this phenomenon lies in the exposure to long working days in computing-intensive environments (Jensen et al. 2002). Subjects, in these situations, end up themselves acting like mere computers, with terse, emotionless responses and an absence of human warmth. Quite commonly, this state of mind manifests in outbursts of anger directed at co-workers when they are, for example, slow to provide answers, or at the electronic devices themselves when they do not function efficiently, among other behaviors. Other nonphysical harmful manifestations that also affect the mental health of people are, for example, the stress and anxiety related to the desire to control technology but the inability to do so, resulting from the continuous development and commercialization of new versions of computers, new operating systems, applications, forms of interaction with technology, etc. One of the most damaging consequences of this stress and anxiety is so-called burnout syndrome, whose most visible symptoms are permanent exhaustion and lack of interest in work. In a similar vein, Internet addiction can be cited, which, through online roles, virtual reality and access to massive amounts of information can generate a feeling of stress at not having enough time to access or assimilate large amounts of information, as well as discomfort or depression when, on the contrary, it is not possible to be connected to the network. The cited manifestations are normally outside the scope of responsibility of educational management teams since they are individual emotional behaviors. However, the incorporation of procedures in the corporate code of ethics of the school, which facilitate the self-identification of addictions or asocial behaviors, can be of great help as a first step for individuals to be aware of the problem and, individually or with assistance, develop skills to overcome stress and anger.

Equitable Access to Individuals

Guaranteeing equal access to information and IT resources is a key issue in trying to ensure that social inequalities do not occur. In this section, we can mention the economic differences that can lead to significant portions of the population being unable to access technology and more specifically the Internet (Gremigni 2018). This situation is known as the “digital divide” and occurs both between continents and countries and within the countries, regions, and communities themselves. This difference can mean in the long term that, in the educational field, there are differences between the level of access and use of IT infrastructure for students, which can condition their professional and social future. This issue corresponds, above all, to political decision-makers in the field of education, although the managers of education centers must be alert to the problem in order to prevent, to the best of their abilities, this type of situation from arising within their sphere of influence. Within this section, it is especially important to guarantee access to technology for groups with disabilities. These groups require access to assistive technologies that enable them to overcome their disabilities and place themselves on equal terms with the rest of the student body. Technological developments have allowed for significant changes regarding this matter. Thus, for example, voice input devices, eye tracking systems, Braille keyboards, etc. have contributed greatly toward reducing the digital divide between students with and without disabilities. Educational managers must ensure the availability of the resources that enable these groups to access information and IT infrastructure on equal terms. It is not only a measure based on an economic condition; it requires a high level of commitment of the part of management teams so that, beyond the mere acquisition of electronic equipment, their effective use is facilitated.

The feminist perspective is another factor that has made its appearance in the field of IT use, although in recent times it seems that the debate regarding the different capacities and motivations related to gender has decreased in intensity. The issue has its origin in numerous studies that

showed a lower level of interest by female students in the use of IT and a lower self-perception of capacity to use it than that shown by males. This situation created some alarm because, if confirmed, it would mean that half of the population could not be easily incorporated into working environments, current and future, based on heavy use of IT. Such a situation would generate a digital divide between the sexes whose long-term economic and social implications could be very negative. However, numerous recent studies point to the fact that it is more a problem of self-perception and self-demand with respect to the use of IT than due to a lower level of competence (Johnson 2012). In this sense, it is an important task on the part of educational managers to ensure that no type of attitude persists that discourages women at any stage of the educational process from attaining the same level of IT proficiency as their male counterparts or, most importantly, encourages a female inferiority complex regarding IT use. If necessary, educational managers should insist that teachers do not accept any difference between male and female students in terms of their interactions with IT systems (Vitores and Gil-Juárez 2016).

Actions to Be Taken by Educational Managers

The typical size of education centers is not on the scale of large corporations or governmental centers, where the volume of employees with access to the IT infrastructure makes it necessary to have a corporate code of ethics in relation to IT. However, the small size, comparatively speaking, of schools should not be a pretext for not developing a specific set of ethical standards that guide the use of IT and handling of information in general. This code could be part of a broader one which would include any deontological or ethical consideration related code of conduct to be followed by all stakeholders. An ethical code of conduct in relation to information and IT should, at the very least, include the following dimensions:

Responsibility and control over information and IT infrastructure. A single person should be designated to be in charge of all information

systems and technologies, as well as manage information. It would be their responsibility to ensure the individual rights of all stakeholders of the education center, the rights of privacy protection, the quality of information systems, and quality of life (e.g., ergonomics, job design, health of employees, etc.).

Rights and obligations over information. The limits of privacy should be established in terms of the use of certain applications (e.g., e-mail) and of the information that the organization has about the various parties, especially the students due to their particular vulnerability.

Summary

The continuous development of IT has meant important changes in the human and social relationships of the people who use it. Undoubtedly, IT has had positive implications that have contributed to improving people's lives. However, other implications have been negative, affecting, among other things, behaviors, relationships, and even the health of IT users. These harmful side effects of IT use are subject to analysis in an effort to discover their causes and the ways in which they can be alleviated. The most common response to the ongoing social and human challenges concerning IT has been the development of codes of ethics regarding the use of information and IT infrastructure. These codes are continually updated according to feedback regarding new challenges that arise and with the experience gained over time. In the field of education, information and IT management also pose ethical challenges. The experience accumulated in other sectors of activity can serve as a reference for actions to be carried out that minimize the negative effects of IT on the various groups that participate in the education system. Educational managers must be aware of these negative effects and address them, leading the development of ethical codes within the education centers for which they are responsible. The success of these codes of ethics depends on the degree of involvement of the management and the motivation that they can muster to achieve their assimilation by all the groups involved.

Cross-References

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ICT-Based Inclusive Education

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Introduction

A discourse about information and communication technologies (ICT)-based education should start with the understanding that, as defined by Gallego (Gallego and Rodríguez 2007, p. 108), “the inclusion movement seeks to construct a new school in which the individual differences are viewed as values and not as problems, and where every member shapes an authentic educational community with a strong sense of belonging.” It should be recalled that for permanent learning to be achieved, it should be initiated by the reflection and the critical thinking of the agents involved, and should concern the relationship between theory and practice, thereby promoting creative learning.

Inclusive education, in general, seeks the active addition of every student in academic as well as social or professional life, and this is the reason why, since the celebration of the Declaration of Salamanca (1994), everyone is

urged to search and eliminate every type of inequality.

As pointed out by Ainscow (2012, p. 40), inclusive education is characterized by aspects such as “a) it worries about every child and youth at school; b) it also emphasizes the presence, participation and academic results; c) inclusion and exclusion are closely related, so that inclusion implies the active fight against exclusion; and d) inclusion is an endless process.” Starting with these aspects, policies can be linked with the resources made available by twenty-first century society to all of its members, meaning that inclusion should be thought of from a digital perspective.

Nevertheless, although this may seem easy, as ICT forms a part of the daily life of most people today, this has contributed to the appearance of two lines of work: on the one hand, the training of teachers on the inclusive addition of ICT into classrooms, and on the other hand, the digital divide. Both of these lead us to discuss e-inclusion and e-exclusion.

E-Inclusion

The introduction of the first computers in education centers resulted in a revolution and a broadening of the shapes and forms of teaching, education and training, as well as learning and our incorporation to active life (Marín and Reche 2011). Thus, a high-quality inclusive education is advocated for, understood to be a basic right and not only as the duty or obligation of politicians, educators, or social agents, as related to the production of transformations that will have an effect in all the facets of a human being.

The inclusion-ICT combination should combine their approaches as a synergy, as a complete e-inclusion that fosters teaching and learning processes that exceed the mere training on the use of a digital resource. Thus, the role of ICT in this pairing should be taken into account from the start. As pointed out by Echataia (2017), the main pillars of inclusive education are, on the one hand, collaborative work, and on the other, networked work, and in this scenario, the

technologies should become a fundamental element for the active and full addition of everyone into society.

Taking into account what has been pointed out by Trujillo and Hinojo (2010, pp. 67–68), the role that the technologies will play in e-inclusion will revolve around aspects such as the following:

1. Potential development of metacognitive processes
2. To increase the ability to develop common collaborative work projects based on an innovative attitude, positioning and philosophy of action
3. To develop cross-cutting themes such as inclusion, interculturalism, constructivism, and quality and innovation
4. To produce educational content based on multimodal creation
5. To irradiate the curriculum with design, development, and innovation with web 2.0 tools
6. To train for the later application on the dynamics of development of the classroom in an efficient manner and based on high quality projects
7. To develop digital competencies and technological literacy in parallel as a result of a programmed structure of teacher's training
8. To establish work networks that last throughout time
9. To develop motivational aspects that promote a person's equilibrium, conditioning him or her towards active participation and commitment with the network created
10. To educate for permanent training as a principle of innovative and constant search in the quest for the attainment of equilibrium
11. To commit to the care of the organization based on values and norms created by the network
12. To evaluate the collaborative work environments as the start and turning point for the knowledge and recognition of individuality
13. To recognize the training on method adaptation required by the teachers on the use of these tools

14. To broaden the work and learn beyond the classroom, school, university or center; or in plainer terms, beyond a specific curriculum and programmed content

Studies such as the one by Ozkan (2015) show that the use of the ICT promotes a great number of learning possibilities, which can and should be transferred to spheres of inclusiveness. They can then become a fundamental element to enable access of everyone into the technological world, resulting in the overcoming of the digital divide, also known as e-exclusion. This last term has brought to the fore the concept of e-inclusion, given that it has brought to light the lack of specific policies that promote it, exceeding the integrative view of the tendencies previously to the boom experienced by ICT, and which are still being experienced.

As a result, it is necessary to train, develop, and achieve a digital or ICT competence that includes “abilities such as the management of information, conflict resolution, creativity, critical thinking, efficient communication, collaboration, work in teams and self-directed learning” (Sunkel 2012, p. 30). Therefore, e-inclusion needs to be discussed. On the other hand, it should not be forgotten that the bringing together and introduction of inclusive education to ICT implies, in the words of Zappata et al. (2011, p. 20), “a process of appropriation of the tool and knowledge, and the construction of concepts that tend to incorporate material and digital resources such as flexible, adaptable and cross-cutting contents.” Within it, social advances, the possibilities of choosing, the availability of resources, the training, the interest, the attractiveness of the interface among other aspects, will imply that they are incorporated into inclusive environments.

Why E-Inclusion Should be Discussed

It is necessary to be conscious that the incorporation of ICT into the education sphere from a perspective of inclusiveness implies the thinking not only about what it is to do, but also why and how.

Answering these questions is not an easy task, as there are many answers to be taken into

account. Thus, there are education professionals who are keen on a participative model, related to collaborative and cooperative work within which inclusion becomes a great referent, and others who, even though they believe that participation is important, do not conceive or think about inclusive participation. Given this duality, an intention can be to provide an answer to these questions from a perspective of digital inclusion.

Why should ICT be incorporated into the practice of inclusive education? Initially, the answer will be to develop or to achieve an improvement in learning and to endow the subject with a greater range of possibilities for participating in life in modern society. Given that this society is digital, it will be necessary to gain digital competence to any level, but also to become digitally literate.

At present, the concept of inclusive education should be linked to the concept of technology uses, given that if the integrative vision of it has been exceeded, it is time to broaden horizons to see where it is possible to go in the search for e-inclusion. This needs to be done from an organizational and cultural perspective that promotes pedagogic innovation, and that facilitates access to new communication processes created by ICT. Ultimately, what is sought with their use, is to break the barriers that impede having a high quality education, and this is found within what has been defined as *Understood: for Learning and Attention Issues* (UDA) (<https://www.understood.org/en>). The principles that underpin the UDA are: representation; action and expression; and participation. The first refers to the possibility of presenting the contents in various formats that are accessible to all; the second indicates that the materials or resources should become accessible for all the students for their interaction; and lastly, it invites the teachers or educators to incentivize the motivation and the interest for using new resources. But for the UDA to be truly effective, it is necessary for an accessible pedagogy movement which supports it, to rest on the curricular development that clearly identifies the learning barriers that the students could have in order to effectively act against them.

Why should ICT be incorporated into inclusive educational practice? The answer could be

concise: its ease of access (Marín and Sampedro 2018), although it implies that teachers must broaden their dedication, for example, by reworking classroom methodology, by redefining it or redesigning it, and it also implies that their participation becomes more creative (Bennett et al. 2012).

Just as Trujillo and Hinojo (2010, p. 63) discuss, it could be considered that digital tools have “opened new scenarios, new ways, different alternatives for participation and relationships, new structures.” In this manner, digital inclusion or e-inclusion could be associated with the creation of new forms of participation by people in society.

According to Luna (2013, as cited in Romero et al. 2018, p. 89), ICT in the sphere of inclusiveness can be classified according to 7 criteria:

- The aim of their use is educational, simulator of independent life, entertainment, accessibility, mobility, and as a communication media.
- The cost of acquisition: high cost, average cost, low cost, and free.
- Medium of access: buying, personalized creation, free download, and online.
- Types of materials offered: interactive resources, resources for printing, and resources for design.
- Type of technology: software, hardware, switch, simulators, virtual reality, and augmented reality.
- Type of media used: videos, audio, images, and animations.
- Type of disability: motor, visual, hearing, intellectual, attention deficit disorder with or without hyperactivity (ADDH), autism, and other development disorders.

These elements will result in teachers needing to specify in which sphere to place themselves for their selection, although other aspects should be taken into account also, such as the availability of economic, geographical, and training resources.

And lastly, how can ICT be incorporated into the practice of inclusive education? Even though diverse forms of incorporating digital tools into the act of inclusion will be discussed later in

this entry, the initial response oscillates around visualizing something, that is, an NGO, an association, a project, bringing attention about a circumstance that demands attention from society, besides wanting to introduce an initiative. The manner or form that can be used for incorporating digital tools into the act of inclusion will begin, as already pointed out, from a vision that is far removed from integration, and based on a vision that proclaims collaboration, cooperation, the action in its broadest sense. For this, it will be important for educators to be trained on their use, as current students are already prepared, as indicated by Silva and Rodriguez (2018).

Training of Teachers in E-Inclusion

The training of teachers has been, is, and will be a constant feature in the education policies in every country. Independently of the training system, everyone in the area of inclusion seeks the same objective: the participation, training, and incorporation of all to have an active life. However, for those wishes and lines of work which the regulations of each state sustain, it is necessary that the variables (the teachers) on which the design and development of inclusive methodologies fall, are trained for this.

Conducting inclusive didactic strategies based on ICT entails that teachers use these resources in a broader sense than the mere instrumental, which implies changing the sense of the verb from a “could do” to a “will do.”

The training that should be given to teachers who will later incorporate the ICT into their classroom practice from a perspective of inclusiveness, starting from a series of aspects such as: learning how to use the ICT as a communication instrument belonging to all and for all; seeing them as an element that amplifies their abilities and competences; using them as an instrument of psycho-pedagogic evaluation; and as an element of entertainment that facilitates the acquisition of knowledge and learning.

It is teacher training centers that need to promote training on the use of ICT from the viewpoint of inclusion, in the broadest sense of the word. Their activities should be supported by previous studies that detect real needs, either

expressed or not, by teachers. Starting from this, the next step would be to design diverse training methods (seminars, courses, training days, etc.) according to the realities of the classroom. The format can be questioned, as a great number of variables must be taken into account (geographical location of the center, availability of the material/infrastructure and economic resources, previous training or lack thereof, physical spaces for the training—in person or virtually, availability of the teachers themselves, who demands the training, and for participation).

The main basis on which the inclusive digital training of the teachers, and on which it should be balanced, is the assumption of a tolerant spirit, based on respect and cohabiting, that assumes the principles of equality of opportunities and democracy for all. This is how curricular sustainability that is needed at this time will be achieved.

Educational Digital Divide or E-Exclusion

The addition of ICT in the life of people has generally resulted in what is now called the “digital divide” or “e-exclusion.” If the digital divide is understood as the lack of possibilities for access to digital resources that facilitate or promote the access to information, education or resources, it is possible to see that it encompasses many kinds of human actions, as this concept implies that other situations of inequality could be produced by it (e.g., the economic impossibility for accessing resources and access difficulty due to geographical limitations, lack of training, type of connection for accessing the resources available on the Web, age, and gender). It should be understood that “digital divide” is a broad and divergent term that provokes at the same time new scenarios for action for inclusive education per se.

In the area of education, discussing it entails that specific moments in the process of learning where it is necessary to conduct individual training events need to be carried out. However, a digital divide or e-exclusion implies that even if ICT resources are being employed in classrooms, these may not be accessible to all the students, breaking away from the principle of equality that promotes inclusive education. The heterogeneity when determining the causes that promote or

provoke the e-exclusion of people in general and students in particular has consequences throughout life, given that as a function of the starting issue that provokes this situation, it will be more difficult or easier to overcome these barriers.

Initially, e-exclusion (digital divide) has a first trigger, which is no other than the economic situation of each community, family, and individual. It is when this is improved, when diverse types of divides begin to disappear. As a result, the development of economic policies designed from a perspective of inclusiveness would then allow access to digital resources to be universal.

The need for education on the use and consumption of different digital devices (tablet, smartphone, computers, and video game consoles) should be considered, and availability of resources should not be negatively affected.

Educational scenarios need to be constructed by the users and the teachers; therefore, the overcoming of e-exclusion is found in two domains. On the one hand, teachers themselves, as already pointed out, need to incorporate ICT into their daily practice of educating as a function of their training, their feeling towards them and their availability, and on the other hand, politicians and education theorists, who are responsible for the management of budgets, which will determine the actions of the former. This last group has a responsibility for not perpetuating systems of social inequality that directly provoke educational inequality.

Web Tools for Inclusion

Bennett et al. (2012) point to the speed with which the Web 2.0 has grown, which has promoted new opportunities, not only for creating, but also for sharing and interacting with other individuals. The latter aspect has been solidified by the different tools that have grown under its umbrella, such as video games, blogs, wikis, photograph and video repositories, or social networks (see Table 1), although as indicated by Maloney (2007), many of them were not born out of an educational or inclusive vision.

ICT-Based Inclusive Education, Table 1 Classification of some Web 2.0 tools according to their type and function

Type	Function	Tools
Communication	For sharing ideas and information	Blogs Audio blogs Video blogs Instant messaging Podcasts Webcams
Collaboration	To work with other people for a specific objective, in a shared work space	Editing and writing Virtual and practical communications Wikis
Documenting	To gather or present evidence of experiences, production, lines of thought throughout time, and so on	Blogs Video blogs Electronic portfolios
Creation	To create something new that can be viewed and/or used by others	Hybrid web applications Virtual communities of practice Virtual worlds of learning
Interaction	To exchange information, ideas, resources, and materials	Learning objects Social markers Virtual communities of practice Virtual worlds of learning

Note: Relationships of Web 2.0 tools according to their classification (Marín and Sampedro 2018, p.403)

This classification will always be in continuous evolution and growth, given that the nature of digital tools is to evolve. The horizon that the Internet leaves open for the creation of new resources should not be ignored.

Social Networks and Web Pages. Are they Inclusive?

The vertiginous development of the Internet in the last decade has resulted in a profound change in the manner of seeing, understanding, and feeling, and about people's places in the world. The Web is the largest window to the world that twenty-first

century man can stare out through, or imagine. Its growth has resulted in changes of social, educational, political and economic perspectives, which, according to Uzunboyly et al. (2011), are linked to three processes: the increase of scientific knowledge; the development of digital culture; and the diversification of teaching modalities. As observed, the three statements come from a positive view of the Web, where the greatest tendency is to share and interact among equals (Schneckenberg et al. 2011; Bennett et al. 2012).

As stated by Prensky (2010), the moment has come when people's contribution to the Web is more important than what they can receive from it, so it is important to incorporate them to the universe of inclusiveness. The rise of the Internet has also brought about the proliferation of a great number of digital resources/tools that can be used in diverse modalities and for diverse objectives.

This philosophy, together with its social side, is the pillar on which the Internet rests. And it is from this social perspective, where the social networks come from, as a catalyzing element of the human impulses and creator of relationships, where it could be said that it has truly meant more than a technological revolution, to one of social character, bringing with it new ways of being creators and apprentices (Holcomb and Beal 2010), in a continuous process of intellectual, social, and emotional growth.

The development of social networks is based on the theory of six degrees of separation which originated with Frigyes Karinthy (1930), experimented and developed by Milgram (1967) and defined as such by Watts in 2003 in his work *Six degrees: The science of a connected age*. Social networks as such were not born with an educational objective, but on the contrary, they complied with a human desire to be connected and informed. It is starting from spaces such as MySpace, Facebook, Instagram, Snapchat, and WhatsApp—iterations of *SixDegrees*—the first social network that was created in 1997 and laid to rest in 2001, that social networks have become popular in academic environments.

Taking into account the classification by Marín and Sampedro (2018) (see Table 1), it can be

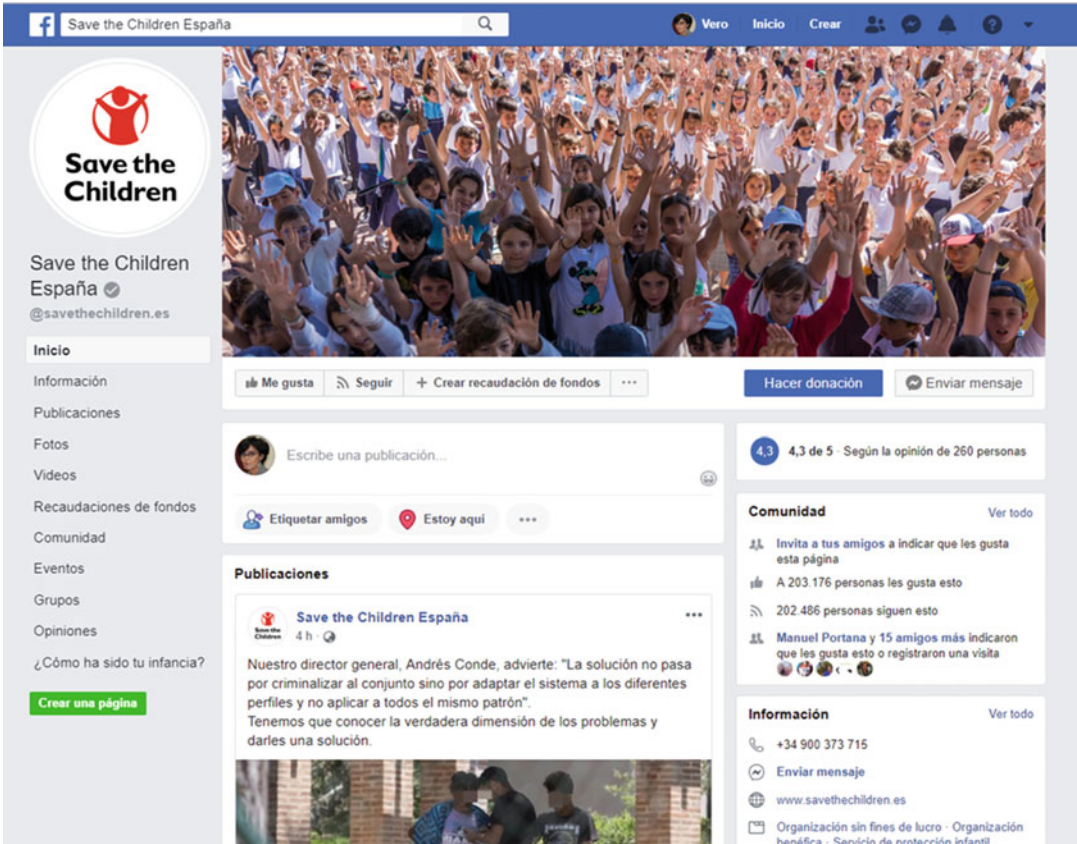
observed that social networks are defined as a unifying element of many other categories, so that they can be understood as serving as a loud-speaker that makes latent the different social realities of the present.

Thus, it can be argued that we should delve into the possible uses for inclusiveness that could be provided by them, starting with the basis from which social networks were born: to meet a communication need, the need to belong to an all-inclusive group, to understand, know, and be up-to-date with what is occurring nearby or far from the environment we find ourselves in. This need is intrinsic to humans, for better or worse, from the moment we are born.

Therefore, the main advantages of social networks would be the possibility to share passions, feelings, hobbies, events, knowledge, information, resources, and materials; to contribute to the growth of collective consciousness; to create cooperation groups, and so on. Trujillo et al. (2015, p. 289) state that “the collaborative social networks represent a great opportunity for promoting active learning, shared experiences, commitment of the teachers and students, etc.,” so practically every organization now has a profile in some social network. But, are they relevant? Or has the time arrived when the social network market in this area has become saturated?

There are as many profiles in Facebook, as in Instagram, or associations, education NGOs, social organizations in the world. All of them have in common that they all show what each of them is doing—the activities, projects, workshops, courses, conferences, publications, in their field of work. Thus, this is how the Facebook pages of Save the Children and the Red Cross is calling for funds and informing about diverse situations of insecurity (see Figs. 1 and 2).

The web pages have become a platform for presenting what the NGOs, associations, groups, and education centers have been doing. Thus, the web page of the Association of Cabildos Indígenas del Norte del Cauca-Colombia (<https://nasaacin.org/>) provides a voice to a collective that does not tend to move far from the frontiers of their own country or continent (see Fig. 3).



ICT-Based Inclusive Education, Fig. 1 Save the children social network, Facebook sites



ICT-Based Inclusive Education, Fig. 2 Cruz Roja (Red Cross) and Médicos Sin Fronteras (Doctors Without Borders) Facebook sites



ICT-Based Inclusive Education, Fig. 3 Web page of the Asociación de Cabildos Indígenas del Norte del Cauca Colombia. (Source: <https://nasaacin.org/>)

Already in Spain, a large number of such pages can be found. For example, the association SETEM Andalusia (Spain) (<http://www.setem.org/site/es/andalucia/>), and more specifically its office in Cordoba, present Cordoba society in general and society in particular, with the actions they are conducting at present through its blog (see Fig. 4).

However, although they can be a great catalyzing element of information and presentation of the projects that are being developed, they also present a great handicap to many people. Many of the web pages that are linked to these projects are not maintained through time, even though they still deal with a relevant topic and a broad group of possible followers.

In this sense, it is possible to see that the web page of the EMATIC project (video of the project on YouTube: <https://www.youtube.com/watch?v=Zzv59tbOH9I>) seeks to address this issue (see Fig. 5), from which one is invited to download an application for the learning of mathematics with ICT, even though it is focused toward students with specific education needs (<http://videm.es/ematic/>). This project was born in 2011, but it has not been updated.

On the other hand, the Erasmus+ PRETTi project (<http://www.pretti.info/en>), with the collaboration of

the University of Cordoba, while not emphasizing the importance of ICT for easing inclusive education, the social networks and the web page are used to present it (see Fig. 6). As observed, it is another perspective of the use of digital resources for inclusion. This project also created a page on a social network: <https://www.facebook.com/Project.PRETTi> (see Fig. 7).

In the area of ERASMUS+ projects, the *Project: Adaptive Personalized System for Creating Expression Tools in Social Inclusion of Learners with Verbal Communication Disabilities – TESI* (<http://tesi.dipseil.net/>) also follows the format of the previously mentioned project.

Augmented Reality at the Service of Inclusion

In the Horizon report for Higher Education of 2012 (Durall et al. 2012), a discussion was started on the active surge of a series of technologies, catalogued as emergent, that were entering the education sphere without halt. Four years later, these technologies, although still defined as emergent, had already become a reality. Among these, the type of technology that has become increasingly used is Augmented Reality (henceforth referred to as AR).

Augmented reality was born under the auspices of virtual reality (henceforth referred to as

Setem
Andalucía-Córdoba

MÚEVETE Y CAMBIARÁS EL MUNDO

"Nadie comete mayor error que aquel que no hace nada porque sólo podía hacer un poco"
E. Burke

Inicio | Setem | Voluntarios '16 | Campos | Proyectos | Actividades | Experiencias

Experiencias '16
viernes, 30 de noviembre de 2018

Carmen 2016
Marco 2016
Rafa 2016
Rocio 2016

Archivo del blog
▼ 2018 (10)
▼ noviembre (4)
"Nankameanuka, imia amutanmak nankanestsui. Iña en...
Jokel Pomena pobagol Pingemisantiro oka? Iroonti...
"Hun noviembrenhmun nokun ishpín kusakinon. Hun no...
Experiencias de voluntariado internacional en Amér...
► octubre (2)
► septiembre (2)
► julio (1)

“Nankameanuka, imia amutanmak nankanestsui. Iña enente iña yacharije ukuknaka nekeñawe” “Lo que empieza, no siempre acaba. El corazón y la memoria saben guardarlo” (Lengua Shuar)

En esta entrada tengo que atinar muy bien, tengo que poner “mucho carne en el asador” y aprovechar para hablarlos de mis gentes. Pero eso sí, voy a ser fiel a la pretensión que tenía con base al mes de noviembre.

El pasado 25 de noviembre se celebró el día mundial contra la Violencia de Género y, como no, ahí estaba yo, metida en la trinchera.

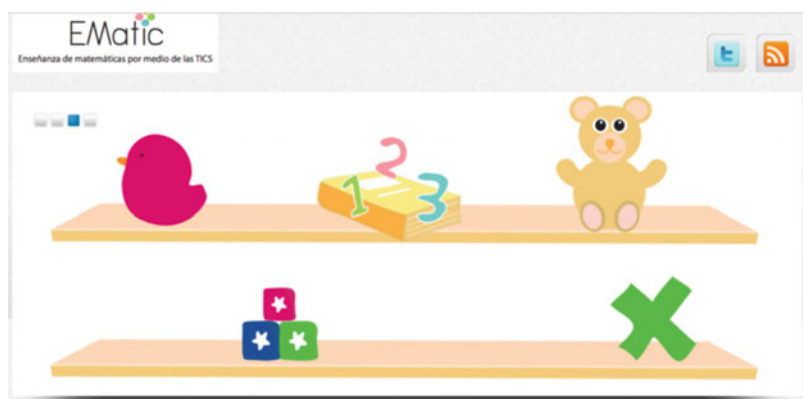
Cuando llegué de Lima, de forma fortuita me invitaron a una reunión donde se hablaría de aquellas actividades que se realizarían desde la Municipalidad de Atalaya; y digo de forma fortuita, porque la circular la recibí mi compañera Edith, que sabiendo mi gran interés en aspectos relacionados con el género, no dudó ni un solo instante en avisarme de tal acontecimiento: ¡Marina, ahí tienes “chamba” de la tuya!

No podría explicaros cómo me siento cuando hablamos de lucha, cuando hablamos de derechos y cuando nuestra arma no es un “machete”, sino nuestra propia voz, las voces que queremos escuchar.

Aunque la realidad sea diferente y el machismo se exprese de otras formas, he considerado muy oportuno implicarme y comprometerme con las mujeres de Atalaya y de forma muy especial con mis niñas de NOPOKI. Entonces, al igual que la señora Mercedes se remangaba para asar el “pollo cangas”, yo me remangué para desmontar todos esos mitos que existen entorno a las construcciones de pareja a través del amor romántico; en eliminar todo tipo de violencia y en utilizar un discurso adecuado para derribar las opresiones a través de la crítica, el análisis y la reflexión. Es bastante gracioso ver sus caras cuando les digo que Cenicienta, en realidad, no quiere compromisos y, además, no come perdices porque es vegetariana. No os voy a negar que en un primer momento

ICT-Based Inclusive Education, Fig. 4 SETEM Andalucía-Córdoba. (Source: <http://setemcordoba.blogspot.com/>)

ICT-Based Inclusive Education, Fig. 5 EMatic portal



VR), as it was considered to be a step forward from it. Although here the focus will be placed on AR, what will be presented is paired with the indirect use of VR, because “when comparing

virtual reality and augmented reality, it is found that their differences comes from the fact that they promote formulas of interaction between the subjects and the real world that are completely



ICT-Based Inclusive Education, Fig. 6 PRETTi project Facebook page



ICT-Based Inclusive Education, Fig. 7 Pretti Project Web portal

different. Thus, while virtual reality places one in a completely non-existent world (virtual) that completely substitutes the real one, AR adds a new plane of vision that is different from one’s view of the real world, adding complementary information through the overlapping with virtual

3D objects” (Villalustre and Del Moral 2016, pp. 31–32).

As for AR, the main objective is none other than to bring closer to reality whatever the students learn in class, with the aim of improving their academic performance. There are different

levels of AR, and according to some authors, these are as follows:

Level 0: Hyperlinks to the physical world (a simple link is applied to the physical world with a QR code).

Level 1: AR with markers (markers are employed over which the digital information is overlapped).

Level 2: AR without markers (image recognition and other techniques are used to overlap digital information).

Level 3: Augmented vision (the next stage of development of AR: intelligent glasses or contact lenses) (Sánchez 2018, p. 21).

Cozar et al. (2015, p. 143) state that the advantages of using AR in education in general revolve around the following aspects:

- Development of cognitive, spatial, perception, motor and temporal abilities of the students, independent of their age and academic level
- Reenforcing attention, concentration, short-term memory and long-term memory in their visual and listening forms, as well as reasoning
- Activation of cognitive processes of learning. AR works in an active and conscious manner on these processes because it allows for the confirming, refuting, or broadening of knowledge and generates new ideas, feelings, or opinions about the world
- Creation of attitudes of reflection when explaining the phenomena observed or to bring solutions to specific problems
- Supplies an efficient environment of communication for educational work, as it reduces the uncertainty of knowledge about an object
- Increases the positive attitude of the students about learning, as well as their motivation or interest on the subject that is being addressed, reenforcing abilities and competences (independence, initiative, and principle of self-activity or independent work)

All of these have an important presence in the inclusive education sphere, and many research studies have studied this. For example, the Chen

et al. (2016) study showed the possibility of using them with autistic children, or the study by McMahon et al. (2015), which presented their advances also with autistic children, besides those with intellectual disabilities. The study by Lin and Chang (2015) explored uses with children with intellectual disabilities, as well as interculturalism and multiculturalism, visual, motor, psychological, and hearing disabilities, or those with high abilities (Cozar et al. 2015; Wojciechowski and Cellary 2013; Marín 2016, 2017). Juan et al. (2014) point out that AR supports spatial memory at the children's education stage, as well as for students with diverse disabilities.

On the other hand, the issues concerned with uses of AR can be identified in the education sphere as lack of teacher's training; lack of resources; lack of time; or the digital divide it creates (Marín 2016, 2017). Nevertheless, the possible positive results of their utilization have greater weight, with this being the reason for its fast penetration.

Focusing interest on the options that can more easily be accessed, at level 0, the use of QR (Quick Response) codes, can be defined as "a two-dimensional matrix of dots that can store a great quantity of information within it" (Sánchez 2018, p. 22). This allows storing a great quantity of information in two dimensions (horizontal and vertical), with this information being videos, images, sound, text, and so on. The main advantage of a QR code is its easy creation.

There are a great number of generator sites on the Web, such as Unitag (<https://www.unitag.io/es/qrcode>), or QR Code Generator (<https://es.qrcode-generator.com>). It should not be forgotten that QR codes can be dynamic or static, with the latter category being more common, and the easiest to create, and the applications – or at least most of them – tending to be free, although some have to be paid for as well. On the other hand, the dynamic ones can be modified many times once the code has been created, while the static ones cannot. Nevertheless, the colors and images used to create them should be taken into account, as the code can become illegible. For example, in the case of Fig. 8, the code with an image cannot be

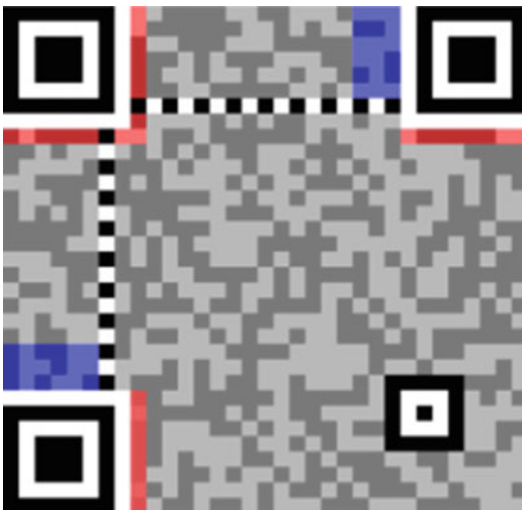
read by part of the readers. Also, the logo of the business/NGO/association, where the user is collaborating/working, can be incorporated into it (Fig. 9).

Among the choices that can be found for working with AR in inclusive education environments, is the project *Pictogram Room* (<http://www.pictogramas.org/proom/loggined.do>), developed by the Polytechnic University of Valencia and the Orange Foundation. As found on its web page, this project “is an entertaining way of making advances in basic aspects of communication, joint attention, the body’s scheme and imitation. Through visual and musical supports, the child or adult have available different

video games with which to learn, taking advantage of its strong characteristics: the visual character of the games, the music and the use of the body.”

“Pictogram Room is a set of entertainment-educational activities that are free to download, designed to provide an answer to a series of needs of people with Autism Spectrum Disorder (ASD), which up to the present has been difficult to deal with. Difficulties in the understanding of the body language, its recognition, imitation or joint attention. . . are critical abilities for the development of the child with ASD. This can be addressed in a fun manner within Pictogram Room, where the children and adults with autism, with the support of the educator and also accompanied with other children with autism, are entertained by playing” (Pictogram Room 2018).

On the other hand, the new application that Google has linked to AR, Google Arts & Culture (<https://artsandculture.google.com/>), works with the arts. This application places the spectator inside 360° views, where the user can enjoy, for example, a tour of the ocean depths in the era of the dinosaurs, or tour a museum room also in 360° (see Fig. 10), or make a selfie and find similar faces in works of art. Alternatively, it is possible to visit a location such as the London Natural Museum of History (see Fig. 11) (<https://artsandculture.google.com/project/360-videos>). All of the tools implemented by this application can be employed with all students, except for perhaps those who have limited vision or blindness, except for those for whom the pictures that



ICT-Based Inclusive Education, Fig. 8 QR Today’s featured article



ICT-Based Inclusive Education, Fig. 9 Static QR Christmas advertisement 2018 Fig. 10. QR creation tutorial



ICT-Based Inclusive Education, Fig. 10 360° image of the Chicago museum

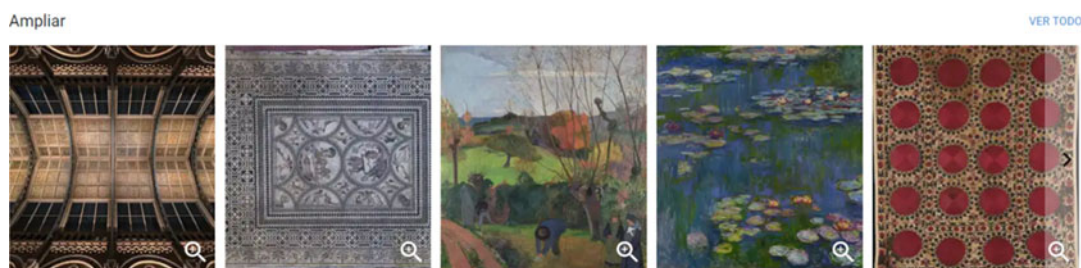


ICT-Based Inclusive Education, Fig. 11 Rhomaleosaurus Sea Dragon: Back to life in 360 VR

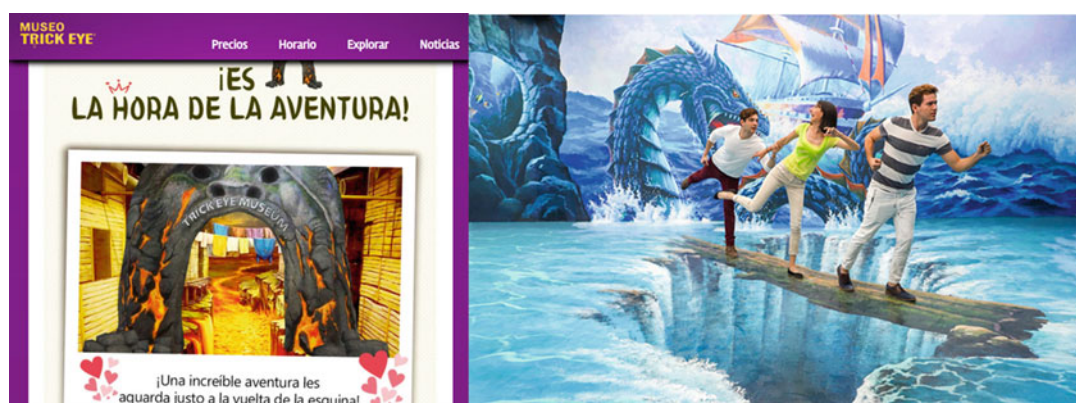
have the option “Amplify” allows for viewing amplified images (see Fig. 12).

A new experience that has arrived in the Latin-American context is the museum TRICKEYE, which began in Singapore and has currently opened its doors in Mexico City (<http://www.trickeye.com/mexico/ARFeature>). This museum

allows the visitor to experience the works of art that are shown “by himself or herself.” For this, the Trompe-l’oeil picture technique is used. With images in 4 dimensions and with different perspectives, the visitor can play with them and experience a work of art in the first person (see Fig. 13).



ICT-Based Inclusive Education, Fig. 12 Amplified works of art



ICT-Based Inclusive Education, Fig. 13 Web page of the TRICKEYE-México museum

The visitor can download an app to be able to project the work of art that is shown in the museum as a marker and “experience” what is shown in the museum in the first person (in its own body and minds). In this sense, and although this could be considered an innovation, individuals with certain disabilities cannot yet enjoy these new experiences.

Nevertheless, despite there being many advances in this field, works such as those by Chiang et al. (2014) and Marín (2016, 2017) have shown that in general, AR is not a valid tool for being used with the visually disabled. However, Caltech has created CARA (Cognitive Augmented Reality Assistant), based on the AR glasses from Microsoft, *Hololens* (see Fig. 14), which will be used by the US army in their training programs.

It should be noted that the Google tool also allows people with limited vision to enjoy the picture works of art, as it incorporates the image

zoom tool, along the line of the results from the work by Lin et al. (2015).

Other Inclusive Education Resources

Artificial intelligence has brought deaf or children with limited hearing closer to reading. The Huawei initiative, *StorySign*, through the free download of an app created for this, allows for the accessing of a library of children’s books, for their later downloading and reading through Star, an avatar who reads the book using sign language (see Fig. 15). This app is available in Google’s Play Store and Huawei’s AppGallery. The books are found in 10 different languages, among which are Spanish, English and French.

An example that makes learning attractive, given that students are initiated on the knowledge of the letters, written as well as spoken, is the resource Literacycenter (http://www.literacycenter.net/lessonview_es.php#), which will

ICT-Based Inclusive Education,

Fig. 14 Hololens



ICT-Based Inclusive Education,

Fig. 15 Star



encourage the acquisition of writing and the speaking of the letters and words in English, Spanish, French, and German.

It is possible to also learn by playing video games, as argued by the group Game Accessibility (<http://game-accessibility.com/game/>). From this perspective, the web page invites the user to delve into the education world through gamification (use of commercial video games not designed for educational use, but those that can be utilized for this) (see Fig. 16).

A stated useful practice of inclusiveness is one that employs video games for the following:

1. Actions that promote learning and achieving of objectives
2. Seeking a high educational level
3. Achieving a lower rate of school rejection
4. Providing a greater depth of/in learning
5. Promoting the inclusion of diverse collectives
6. Developing diverse abilities and skills

7. Invigorating the relationships between members

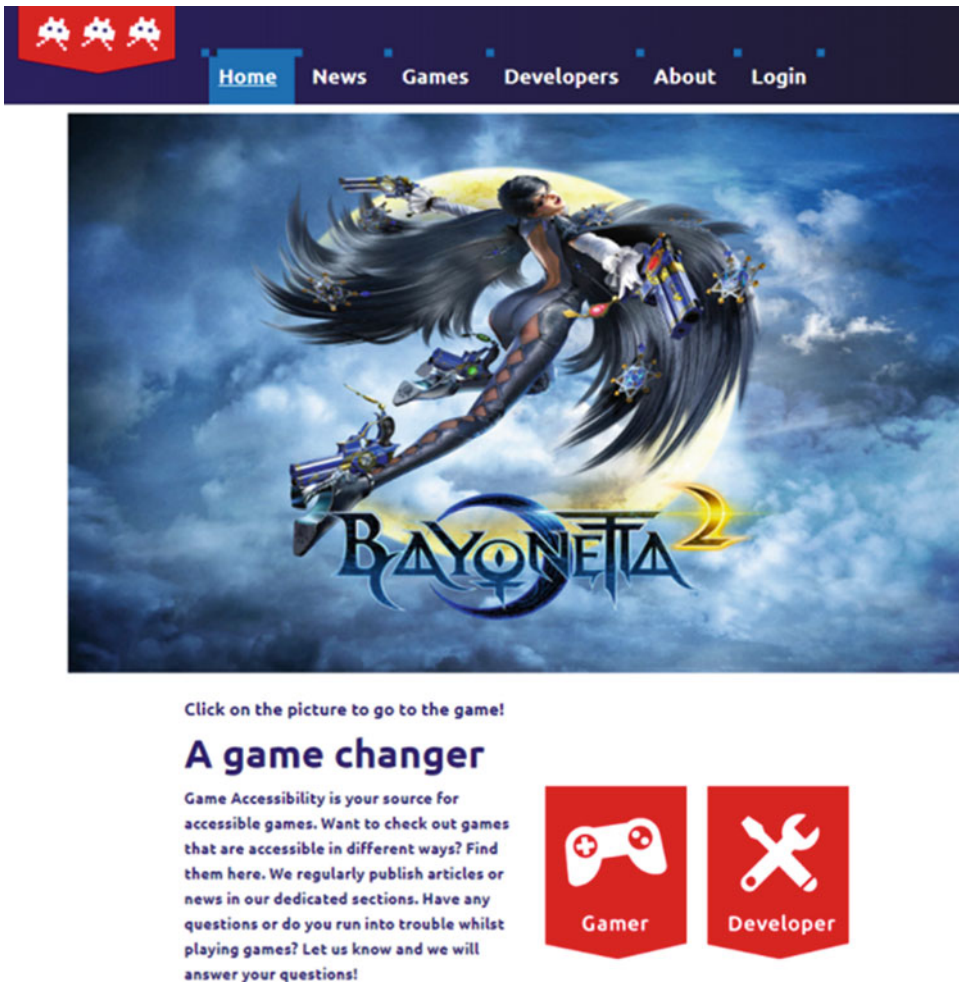
8. Introducing values and processes of reflection

9. Offering diverse competences

Conclusions

It is well recognized that ICT will not substitute for a teacher but, on the contrary, should be understood and accepted as an element that mediates the processes of teaching and learning (Romero et al. 2018), given that when ICT is incorporated into the area of inclusion, challenging spaces are promoted that can call into question the principle of equality that inclusive education seeks.

Promoting learning and the collaboration between subjects, mediated by today's digital tools, allows for social interactivity, and as a result, the development of a digital inclusive



ICT-Based Inclusive Education, Fig. 16 Game Accessibility portal. (Source: <http://game-accessibility.com/game/>)

education. This is based on the belief that all technological resources will and should be understood, utilized and made available to and for all, independently of the physical, psychological, social, economic, or educational situation they are found in.

Education professionals, as pointed out by Gelastopoulou and Kourbetis (2017), feel the need to incorporate ICT in general, and Web tools in particular, to their day-to-day practice. As Marín (2018) indicates, “the ICT-inclusive education pairing leads us to think about two elements that must converge strongly for a single aim: the improvement of the training of the individuals in general and of society at large. This

improvement should begin from a new approach that will appear from the figure of the teacher, mainly,” and this is where all efforts must come together, as what is transmitted can be what is felt and thought, in terms of concerns, efforts and beliefs, as well as values, and countervales, and this is why this matrimony is “obligatory,” to understand each other.

E-inclusion must allow for the evolution and growth of every education system, so that it can be understood as an element that is inherent to the system itself; ergo, the design of actions that do not promote digital equality should be avoided, in favor of a society that is just and egalitarian.

Cross-References

- [Augmented Reality in Education, Scope of Use and Potential](#)
- [ICT-Based Inclusive Education](#)
- [Technology Enhanced Learning](#)

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ICTs in Secondary Education

- [Implementation of ICT in Secondary Schools](#)

Identity Commitment

- [Predicting ICT Skills and ICT Use of University Students](#)

Images

- [Educational Resources, Hypermedia](#)

Implementation

- [Information and Communication Technologies in Chilean Schools, from Enlaces to the Present Day](#)

Implementation of ICT in Secondary Schools

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Synonyms

[Computer assisted learning](#); [Higher secondary education and ICT](#); [ICTs in secondary education](#); [Informatics in secondary education](#); [Integrating ICT in secondary education](#); [Introduction of ICT in secondary education](#); [Lower secondary education and ICT](#); [Personalized learning](#); [Transforming secondary education by ICT](#); [Use of ICT in the classroom](#)

Overview

In this document we will address how secondary schools (with pupils in the age of 12–18) can implement ICT in their educational system. We will use three different models or frameworks to guide such implementation. At first we distinguish between two ways of looking at ICT in education. On the one hand, educators can use ICT to improve the quality of the educational setting and the learning outcome. On the other hand, ICT should be regarded as a subject in the curriculum: learning about informatics, computer science and information literacy, and developing ICT skills. Being aware of the differences between those two ways of looking at ICT in education, we can use a model for implementation which will be described in Chapter 2. The model consists of five phases of awareness, involvement, and consequences, elaborated on in a paper written for and commissioned by UNESCO (Hogenbirk):

1. Phase 1 is the acknowledgement that ICT is a not negotiable, integral part of the learning environment in the education of the twenty-first century.
2. In phase 2 we focus on the learning *about* ICT and ICT skills. In this phase we address ICT literacy culminating in computer science or informatics. But we will also look at the so-called twenty-first-century skills, in which ICT skills play an important role.
3. Consequently or parallel teachers are using ICT in the classroom as a pedagogical tool: learning supported by ICT. Phase 3 concerns a modest way of usage by the teacher him/herself and by the pupils at home. This is a substitution stage of using ICT in the pedagogical process.
4. A next phase is the widespread usage of ICT within the classroom by the pupils and the teacher in a variety of learning activities. This is an integrating stage of using ICT in the pedagogical process.
5. Finally ICT can change the organization of education, by personalization of the learning process. We could call this the transformation stage.

In the chapter “Four in Balance, a Model for Actual Development of ICT-Rich Education at School” we will go into more detail about the conditions of implementing ICT in education. We will use an approach in which four sets of conditions should be in balance with each other, the “Four in Balance Model.” This model is developed by Kennisnet, the Dutch National Centre of ICT in Education (Kennisnet, see <https://www.kennisnet.nl/about-us/>).

Schools should have a vision on the usage of ICT in terms of the objectives they want to serve with it, how they want to use it, and what results they want to accomplish. Secondly the professional development of the teachers should be in line with the formulated vision. Thirdly the software tools should fit the requirements needed. Fourthly, the hardware infrastructure should be sufficient and adequate to accommodate what is necessary.

Finally we will present in the chapter “The P2V Framework for ICT Implementation” a framework for the assessment of the state of ICT implementation in a particular school, to be used by external inspectors or as a self-assessment tool by the school itself. This framework was developed in the European P2V project (Peer to Peer networking for Valorisation) performed by several European school inspectorates (van Oel et al. 2009a).

Introduction

Starting in the early 1980s of the past century, the educational community – practitioners, teacher trainers, and educational researchers – has been working on the introduction and implementation of computers in education. These efforts were attached to the notion that society was entering a new phase. Beniger (1986, From the lemma: “Information Society” in Wikipedia.) showed that the term “information society” was one of the many notions used to described this change from an industrial society to a society where information plays a dominant role in economics, politics, culture, and education.

At first, there were attempts to familiarize young pupils with the achievements of the “new era.” Educational materials were written to practice working with computers; educational software was developed for applying in the different disciplines; national projects were established to supply schools with computers, mostly in separate computer labs; and courses were given to make teachers familiar with the new technical and didactical aspects of computers and educational software.

There were two main reasons for all these activities:

1. Pupils should learn to be skilled in using information technology (IT at that time) as part of the core curriculum (“computer literacy”).
2. At least politicians and educational forerunners thought that IT could improve the outcome of the educational process (and as a side effect, make education less expensive). This type of support by IT was called CAL, computer-aided learning.

In these two objectives, we already see the distinction between learning *about* IT and learning *by means of* IT.

In the 1990s, the Internet popped up as a source of information. Windows brought a much more attractive design for the software. Computers appeared in the classroom – at the back of the room or at the teacher’s desk. Projectors could be used for demonstration purposes. Administrative software was developed and replaced written reports. Assessment tools became available, electronic calculators changed the mathematics curriculum, and word processors made spelling less relevant. IT became ICT! It was not any longer only about the rather static use of data and information, but the digital revolution also changed the way of communicating.

In many countries politicians declared the usage of ICT in education as an inevitable and thus “normal” way of doing in education. But they forgot that principals, teachers, parents (!), and perhaps also the students did not recognize that importance in the same way, and the full

implementation of ICT in daily practice in the classroom did not take place.

In the present decade of the twenty-first century, the smartphone was developed, appearing in every child’s pocket, social media became very important and sometimes dominant, and the information within the Internet is overwhelming: the usage of ICT in daily life indeed became “normal” and inevitable. Nevertheless schools are still wrestling with questions about the necessity, the usability, the effectiveness, and the reliability of using ICT in the educational process, and thus we still see a lot of schooling activities where ICT do not play any role at all.

There is still debate: some doubt if the school should not just resist to the use of ICT in the safe and protected environment of the school. Educational experts investigate the added value of educational computer programs but are hardly capable of “proving” the positive effects. The investments of schools in ICT infrastructure are enormous, and the vulnerability of the systems is a threat for a continuous and stable educational environment. So it may be a good moment to mark time and consider carefully why we should invest in the usage of ICT in education.

Five Implementation Phases of ICT Awareness and Involvement and Their Consequences

We will present a model with five phases, stages, and consecutive argumentations for using ICT in education. We developed this model in a paper commissioned by the UNESCO (Hogenbirk) and applied the model in several cases of advisory processes with individual schools. It brings clarity to the management of schools in where they stand in their implementation process and what they can do to bring that process forward. The phases presented are not necessarily following each other chronologically. Also they are not scientifically independent. They actually address different perspectives of ICT usage in education. Nevertheless they represent in the presented order more or less the recent history of the development of ICT in education and in most cases the way the

implementation process in particular schools develops. In all phases we will give some examples to clarify and illuminate the nature of that phase.

We will begin with the phase in which we acknowledge the necessity of bringing ICT into our schools.

ICT in Education Is Not a Choice

Society is rapidly changing due to the tremendous impact of ICT used by almost all people, including of course the youngsters in our educational system, often referred to as the “digital natives” (Prensky 2001); “Generation Z” (see e.g., generationz.com.au/characteristics), for young people born between 1995 and 2009; and the “Net Generation” for pupils who are now growing up. McCrindle (2014, <http://mccrindle.com.au/the-mccrindle-blog/what-comes-after-generation-z-introducing-generation-alpha> with illustrative infographics) uses the notion of “Generation Alpha.”

The use of ICT influences to a very high level the lives of the kids who are present now in our educational system. The communication between them, the way they play, the information through the media, and the way they are looking at themselves and at their peers and relatives are greatly influenced by ICT in all forms available: computers, tablets, smartphones, the Internet, apps, social media, etc. There is a lot of positive interaction and communication about things happening in their daily lives (yes, also about school-related issues). But also bullying is done digitally. Lover boys are operating by smartphones and dating sites, and digital fake news is a new word for an old phenomenon.

All of this cannot remain without consequences for education. Pupils growing up in the twenty-first century would consider a school without ICT as an unworldly situation. And it is probably just for this reason that, all over the world, initiatives are emerging to turn over the ways we educate. A class full of youngsters, growing up with new technology all around them, cannot be approached by old-fashioned methods, learning materials, and curricula. In a new learning environment, ICT should play a significant role,

clockwise or counterclockwise. So we would state here that education and ICT are an enforced marriage. All other reasons to use ICT are arising from this first notion: we cannot place teaching and learning in an environment that is not mirroring and reflecting the world outside the walls of the school.

It is good to articulate this premise here again clearly, because there are opposing views. One of the most well-known is the view of the German sociologist and pedagogic Thomas Ziehe (1999) who has been fighting since the 1970s for an education that offers students insights and methods just disconnected from their experiences outside the school, called “Alltagserfahrungen.” This kind of noise is also heard in columns in the newspapers and in associations of concerned parents and teachers, with reference to their own childhood and the – often idealized – past.

From the foregoing it will be clear that we should regard these views as background battles, comparable with opposing the (“pernicious”) art of printing in the fifteenth century, the (“dangerous”) transport by train in the nineteenth century, and the (“hazardous”) driving in an automobile or watching television in the twentieth century.

In our view the educational community is obliged to itself to explore new paths for teaching and learning, with conservation of the numerous good elements within the traditional ways of teaching and learning. But only acknowledging this is not enough to fulfill phase 1 in our model. The notion presented here should be reflected in a preamble of the school vision on the way education should be performed, supported by ICT, in a particular school. And this preamble in the vision should be attached to other principles and starting points of the school’s pedagogical identity.

ICT as an Objective of Its Own

Since we now have established the absolute necessity for an ICT-rich learning environment, the need arises to give attention to learning *about* ICT and the development of ICT skills. Of course this is not a new sound. Since the 1970s, the educational community has been discussing the character of insights, knowledge, and skills of ICT

or ICTs. The names of the learning area vary and evolve. We have to distinguish between lower and higher secondary education.

Digital Literacy in Lower Secondary Education

In lower secondary the original name “computer literacy” has been replaced by “information literacy,” “media literacy,” or “digital literacy.” This area consists of a series of communication competencies, including the ability to access, analyze, evaluate, and communicate information in a variety of forms, print and nonprint including messages and also moral and ethical issues concerning the use of social media and the Internet (NAMLE, see National Association for Media Literacy Education, <http://namle.net/publications/media-literacy-definitions>). There are numerous descriptions of the content of this subject. Good examples are the new curriculum that has been developed recently in Australia (2013) or the somewhat older Standards for Technological Literacy from the International Technology and Engineering Educators Association, ITEEA (2006). Other recent examples are from the British Open University with the publication “Integrating IL booklet” (2010) and the ANCIL project with a description of information literacy (2011).

Twenty-First-Century Skills

Another way of addressing the skills involved in this subject area is to consider them as part of the so-called twenty-first-century competences. The European Union published a set of eight competences which cover a wide area of education as a whole (2006): communication in mother tongue, communication in foreign languages, mathematical competence and basic competences in science and technology, digital competence, learning to learn, social and civic competences, sense of initiative and entrepreneurship, and cultural awareness and expression. Organizations like Partnership for 21st Century Skills (P21, Partnership for 21st Century Skills, see www.p21.org), NET/ISTE with the National Educational Technology Standards (2007), and Assessment and Teaching of 21st Century Skills (ATCS, see [http://www.microsoft.com/education/en-eg/leadership/Pages/](http://www.microsoft.com/education/en-eg/leadership/Pages/assessment.aspx)

[assessment.aspx](http://www.microsoft.com/education/en-eg/leadership/Pages/assessment.aspx)) have performed research in the past years to establish the “ultimate set” of competences needed for the twenty-first century. Voogt and Pareja Roblin (2010) concluded in a comparative analysis that all of these studies have in common that they focus on conceptual and meta-cognitive knowledge and skills with respect to communication, collaboration, socio-cultural awareness, and ICT skills.

Comparing the different views and approaches on these competences, we defined four more or less distinct areas of competences (Hogenbirk):

1. Learning and thinking skills: critical thinking, problem-solving, learning to learn, creativity, and imagination
2. Social skills: communication, collaboration, responsibility, and accountability
3. ICT skills: information, media, and technological literacy
4. Life and career skills: citizenship, cultural awareness, self-regulation, and leadership

So if a school is paying attention to ICT skills, the school is also showing commitment to the wide scale of competences needed to be a responsible and well-prepared citizen and worker in the fast-changing future.

In most countries there are objectives, a curriculum, and materials available for teaching and learning this particular area (OECD 2006). However there is often a debate about the way the subject should be taught and the skills should be developed in schools. The core of this debate is if these objectives should be taught as a separate subject with a specialized teacher or if they should be part of and integrated in other subjects, such as mathematics, sciences, social studies, and even arts. At this moment in a lot of countries, the pendulum is at the side where governmental bodies recognize the necessity of some kind of obligatory curriculum on information literacy. Although pupils might be “digital native,” it seems more necessary than ever for children to learn how to deal with information, which ethical and legal aspects of digital information are involved, how to deal with social media on issues such as bullying or privacy, and how to guard

themselves against being constantly online and therefore not being able to concentrate on a more difficult learning task.

In cases where there is no hard curricular obligation from the government to teach the subject separately, we advocate here to consider carefully at the school level if there is a need for a separate discipline with separate teaching classes or if the school and the teachers are able to collaborate on integration of ICT and ICT skills in different existing subjects.

Computer Science

In higher secondary education, the situation is a bit different. Mostly it is expected that pupils already have enough basic skills and knowledge on the use of ICT. What remains here is the somewhat “harder” side of ICT: “computer science” or preferably “informatics,” sometimes referred to as “computational thinking” (Wing 2006), which consists of programming and logical, algorithmic thinking. Other parts of this separate discipline are the hardware technology, information and (big) data analysis, security issues, robotics, and the Internet of Things.

In best cases informatics is offered at higher secondary schools as a nonobligatory choice discipline.

Conclusive Remarks

Defining ICT content and competences on different levels is a major task. First of all because we are talking here about a very fast evolving and changing area of content and applications which makes the educational assignment for every school extremely complicated. It is about creating an environment and a curriculum where all of these skills and content can be practiced, developed, and finally assessed, and choosing carefully what elements should be obligatory and which should be free to choose.

Curriculum elements in which these skills are taught and in which they play a massive role can be found in all subjects in secondary education, in project-based education, in inquiry-based learning, and in more informal outside-school learning activities like excursions and internships. In most of these curriculum elements, ICT plays a

supportive or even dominant role. So the boundary between teaching and learning these skills and using ICT for enhancement of the learning in general is in most cases not very strict. That brings us to the third phase of looking at the implementation of ICT.

ICT Usage for Enhancement of Teaching and Learning: Substitution

So far the reasoning in this entry to use ICT in education is as follows:

- Children are facing and living in a new ICT-rich outside world. To reflect this world and to prepare them properly for a life after school, we are obliged to deliver an ICT-rich learning environment.
- Children should be able to handle ICT within this learning environment and outside school. For that reason, ICT skills must be taught: to handle information, to be able to use computer programs, and to have some awareness in computational thinking.
- In the society of the twenty-first century, traditional knowledge is not enough. ICT skills are part of a bigger collection of the so-called twenty-first-century skills, which have to play a much more prominent role in the teaching and learning practice.
- To design that practice, we have to integrate the use of ICT in every learning situation where it is possible and appropriate.

Recognizing ICT usage as a profitable tool in education leads to the question how far this usage goes. The range of activities where ICT can be used for pedagogical purposes is enormous. In this third phase of looking at it, we focus on the pedagogical use of ICT by teachers in their classes and by pupils doing homework. It is a phase of mostly substituting traditional pedagogics by ICT applications. ICT is mainly used for illuminating specific topics. A biology teacher presents a short movie about the way penguins live, a geography teacher shows a digital map on the screen, in physical education the perfect Fosbury Flop is shown on YouTube, and in art classes paintings can be discussed

with the whole class. Teachers can project the timetable of the class or a specific assignment on the screen, which they have prepared at home, and with no waste of time in the classroom.

The advantages of this type of usage are obvious: it is easy doing, motivating, clarifying, clear, and cost-effective. Although the last advantage could be questioned, because the projector is an investment, the bulb has to be replaced, there has to be Internet connection for some purposes, you always have to be prepared for a failure of the equipment, and there is a need for technical assistance. Giving pupils digital assignments for homework is also part of this phase. Sometimes one can make use of digital add-ons to courses in print, sometimes called “iPacks” or “e-packs.” Author teams of educational textbooks have made strong efforts to invigorate their courses with ICT assignments, graphics, exercises, short movies, etc. The advantages are easy to determine. The teacher can still use “old-fashioned” materials, within his or her traditional approach. It is easy to use these little extras for homework, lost moments in the classes, and extra work for remedial or deepening usage. It has also been the ultimate reaction of the educational publishers to this innovation of their text-based learning materials. They do not have to change their business models completely and can just go on selling books as they were used to. But is this way of using ICT enough? ICT is playing a marginal role in the teaching and learning. It just modernizes the traditional teaching and learning a bit.

By using ICT in this way, one is *substituting* traditional teaching and learning methods and materials by somewhat more contemporary means, but, in essence, not much changes.

ICT Usage for Enhancement of Teaching and Learning: Integration

A next phase in using ICT for pedagogical purposes is to really *integrate* software in the teaching and learning process. The difference with phase 3: substitution is that this type of usage is really changing the pedagogy, often leading to other learning outcome and surely motivating

the learners in a way they are used to outside of the school. We will give some examples of ICT applications a teacher can use.

Educational Software

At first there are specific educational programs. Examples are numerable. See, e.g., the list for educational programs on Wikipedia (2006–2017, see e.g., http://en.wikipedia.org/wiki/List_of_educational_software). Simple programs can be used for exercising foreign language words, topography, historic timelines, chemical reactions, fill in exercises, texts with missing words, multiple-choice quizzes, etc.

Complete and more open environments are available, e.g., in mathematics, to practice calculating, to draw graphs, to explore geometric figures, and to make algebraic or statistical calculations; in music we have the composing programs, and in physics there is software for constructing electrical circuits or controlling and measuring physical phenomena, and there are drawing programs, programs for book-keeping, etc.

There is hardly any debate on the benefits of these types of programs. They are efficient in using and easy to handle and set up, and they make learning activities possible that were far out of reach before.

Simulation Software

A special category of educational programs are the simulation games. The term “gamification” describes situations in which game thinking and game mechanics are used in nongame contexts such as education. Subcategories are adventure games, puzzle games, role-playing games, strategy games, sports games, and even first-person shooter games (Oblinger 2006). Examples of simulation games are text adventure games, SimCity, a blood typing game, management and business simulations, global warming, soccer playing, etc.

Benefits of using games in an educational setting have been measured when the games are used in a proper context, for a specific goal (Griffiths 2002). They can increase student motivation, stimulate interaction and discussion between

students, and place learning stuff into a broader and more relevant context.

Generic Software

While almost all of the programs mentioned here are dedicated to one specific discipline, subject, or curriculum element, a more general way of integrating ICT in the classroom is the application of generic tools. This category contains the word processors, spreadsheets, and presentation tools. Even more generic is the usage of programs like Google apps, Dropbox, etc.

There are also generic programs, especially developed for usage in education. First of all there is the digital assessment software. In this category we find dedicated tests, sometimes as a part of specific learning material. Very usable are the general sites for training exam tests. Thousands of students know how to find these sites without any advice from the teacher. At the other end of the spectrum, we find open assessment tools in which one can import professional tests or in which teachers can develop tests themselves. There exist free to use programs like Testmoz or Questbase and more sophisticated commercial programs like Question Mark and Quayn. Sometimes assessment tools are integrated in the more complete digital learning environment, which will be discussed in paragraph 2.5, because it influences the organization of the teaching and learning.

Other examples of generic programs are Socrative, which enables teachers to engage their students in a class discussion being active with their tablets, laptops, or even smartphones by real-time questioning and visualizing the results; MindMeister, which enables teacher and students to make mind maps of their ideas, foreknowledge, solutions, and brainstorming; and StickyMoose, a tool for collaborative decision-making; etc.

When we look at the usage of iPads, a lot of generic tools are available. We mention some examples: Book Creator or iBook to make your own teaching material or for kids to make their own reports of a project; Explain Everything for writing and importing images and video in one

environment; Vittle Free, which is an interactive whiteboard video recorder to teach concepts and show presentations; iMovie to make or use videos; GarageBand to compose and make music; etc.

The advantage of open generic software is indeed the fact that it is open: teachers and students can use it for multiple purposes, at school and at home, at moments they can choose themselves. You may see in schools that pupils are just using this software at their own convenience. This usage contributes to the more or less informal learning of ICT skills or the informal achievement of ICT objectives (from phase 2 in the model we use).

The Results of Using ICT

At this point we should pay attention a bit to the effects of using ICT tools in the pedagogical teaching and learning environment. Over the past 30 years, a lot of research has been conducted to “prove” the positive effects of ICT on the learning outcome. Well-known is the work of John Hattie who studied 76 meta-analyses of almost 4500 papers using statistical methods to compare the effectiveness of all kinds of teaching and learning strategies and circumstantial conditions (Hattie 2009). In this meta-analysis, research on the effect of ICT usage is very well represented. Yet in his “top ten” of aspects which are most effective, the use of ICT *as such* is not mentioned. But indirectly one can say that some teaching strategies do benefit from the use of ICT. In a comment Steve Moss (2014) identifies six aspects from Hattie’s study which should have most effect on the learning outcome. And for educationalists, these aspects are not really surprising: diversity of teaching strategies, multiple opportunities for learning, students having control of their own learning, and peer-learning and feedback mechanisms which should be optimized to gain maximum outcome. This leads to the conclusion that it is the (difficult but challenging) assignment of practitioners and researchers in education to find the best ways of using ICT for enabling these types of pedagogical success factors.

ICT Use for Changing the Organization of Learning: Transformation

The boundaries between the different types of using ICT and accessory objectives are not always strictly determinable. Yet there is another category of programs and digital environments which is primarily meant to be used as a tool supportive to the organization of the teaching and learning process. It is emphasized here that this type of use could be the most far-reaching. It really could change long-lasting traditional paradigms in education and contribute to the aspects that were mentioned in the previous paragraph that are most effective to improve the learning outcome. So we call this usage of ICT *transformative*.

Two basic leading principles could change the traditional way of teaching. The first is the recognition that every child is unique. So teaching is most effective if it meets the individual needs of the students and if the responsibility of the learning is basically given to the learners themselves.

The second basic principle is that collaborative learning (or peer learning, group work) is an effective way to organize learning situations. In the contemporary reality of schools, these principles are hard to realize. Many factors, such as class size, available, often scheduled time, and lack of usable learning materials, hinder teachers to respond to differences between pupils and make collaborative arrangements impossible. We will elaborate a bit on both principles in relation to the use of ICT and also try to combine the principles because at first sight they may seem a bit contrary to each other.

Personalization

The UNESCO Policy Brief on personalized learning (Izmestiev 2012) presents different definitions of personalized learning. Here we will use the following definition:

Personalized learning is a way of organizing the learning process in terms of content, learning environment, and learning outcome, so that it meets the personal (cognitive) abilities, learning

style, interest, and context of the learner in the best way possible.

Personalized learning can be accomplished in three different stages: working independently, independent learning, and self-responsible learning. In the first stage pupils work on their own assignments given by the teacher. If the students themselves are in control of the way they want to achieve the learning goals, we call it independent learning. What the goals are and how they are assessed are still determined by the teacher. Finally self-responsible learning is the situation in which students determine themselves (part of) the objectives and the way the assessment takes place.

In all of these different stages, ICT can play a crucial role to realize personal learning paths. Let us sum up the advantages of this way of organizing the learning:

- Students can learn on their own level of cognition; this also means that learners do not need to be put together in homogeneous groups; pupils of different ages and abilities can be mixed up and work side by side to each other.
- The learning is less bound by time and place; even holidays can be customized to the wishes of parents and to the need of the children.
- Various learning styles and various interests can be accommodated.
- Because of these aspects, the learner's motivation will increase.
- The learning can be recorded and constantly monitored by the pupils themselves, by teachers, and/or by the parents.
- If these data are correctly analyzed, the learning can be made much more adaptive to pace and level of the pupil and make suggestions for the next steps or interventions in the educational process; in this context we speak of a new area of expertise: the so-called learning analytics.
- If performed with a proper setup and accompanied by proper coaching, the students can better understand their own learning and develop the valuable competence of "learning to learn."

Collaboration

Personalization does not mean that all learning activities should be strictly individual. On the contrary, many activities could be carried out collaboratively, in social and/or intellectual peer groups. Also in peer groups, the nature, level, and pace of the assignments can be harmonized with the individual demands of the learner. In fact we can distinguish here similar stages of involvement like we did for personalization: we can organize cooperative working when students are allowed to work together on a certain assignment. If the way of performing a learning task is left to the group, we call it collaborative learning. If the group decides itself about the content, methodology, and way of presenting the outcome, we could speak of learning with collective responsibility.

Some schools experimenting with different types of learning, individually and collaboratively, have built common educational areas, sometimes called “learning squares.” In those areas pupils of different levels and ages are mixed, working alone or together on different tasks. Teachers and other coaches are walking around to give support and ask the right questions.

ICT Arrangements for Reorganizing the Learning, E-Learning

Having set the two basic principles of new ways of learning, we can search for using ICT in these settings. If the learning is completely ICT-driven, we speak of e-learning. A new methodology for that is the MOOC, the massive open online course. This is an online course aimed at open participation for all through the web. Some MOOCs provide additionally communities for interaction between learners and teachers. This way of learning is a new phenomenon used at open universities and commercial training, but not too much in secondary education. MOOCs are new, and therefore there is not much research available on their outcome and effectiveness. First experiences tend to the conclusion that it takes very self-responsible learners to perform a MOOC until the very end. Less extended ways of online learning can be found, for instance, at the Khan Academy where more than 150,000

smaller and larger courses at all levels are provided.

Blended Learning

In basic education e-learning is still not very much used. The reasons are well-known. Schools are held responsible to a large extent for the learning outcome, often have to deliver according to the law a specific amount of education time, and therefore hesitate to hand over the responsibility for the learning to the children.

But as we have seen, it could be very profitable for the learning effectiveness just to do that. And there we arrive at the term blended learning. In most cases this is defined as a mix of traditional and online or ICT-driven educational settings. Furthermore Oliver and Trigwell, who presented the term first, point out that blended learning also involves different types of instruction, behavioral principles, and strategies (2005).

Of course all sorts of educational software mentioned in the previous paragraph can be used in different intensities in teaching and learning settings. This intensity determines if one would call the learning blended or just traditional with a modern flavor.

Digital Learning Environment

Personalization and customizing the learning to the learner could also be derived from the intensity with which a digital learning environment (DLE) is used by the school or the individual teacher. Such an environment enables teachers to plan lessons and homework, to set up individual or collaborative assignments and tests, and to monitor results and learning reflections. DLEs are not new. In 1997 we already presented a model for “An educational tool for planning and monitoring the teaching-learning process in Dutch secondary education” (Hogenbirk 1997). Despite a lot of effort, the actual construction of the tool never took place.

Now there are numerous DLEs available. Because of high development costs, most of them are commercial. Moodle is a well-known DLE, free of charge. iTunes U for iPads makes it possible to present all kinds of assignments and materials to the learners and colleagues in and

outside the school. ZuluDesk Teacher is a mobile device management tool for iPads with which teachers can manage the learning at the students' devices.

The functionality of DLEs differs. At a minimum level they comprise the possibility of planning, arranging, and supporting the teaching and learning process. They differ in the way they offer the possibility to arrange different learning paths, to approach learners individually, to use portfolio facilities, and to monitor results through learner tracking and management reporting tools. Especially the portfolio functionality is important. A portfolio allows students to store their learning activities, to present results, and to reflect on their own process. Just those features make a portfolio suitable for self-responsible learning.

Flipped Classroom

Another very promising way to change the organization of the teaching is the flipped classroom. In essence this is a form of blended learning where instruction and processing are interchanged. The homework consists of the watching of an explanation or instruction of a certain phenomenon before the school class starts. In the class students can work out assignments with the things they learned in the video with guidance from the teacher, or they can have extra instruction or explanation. There has not been done much research yet about the learning effectiveness. Jensen et al. (2015) found that the "flip" as such does not benefit the learning. But in this research arrangement, the flipped classroom was embedded in a constructivist pedagogy, meaning that students were actively engaged in the material. And this combination leads to improvement of the learning results.

Internationalization

In order to match the goal of citizenship and cultural understanding, it is useful to mention collaborative international projects for children. Initiatives as iEARN (worldwide) and eTwinning (in Europe) provide many possibilities for projects where pupils collaboratively work together on a certain topic. In a "whole

school approach," there is also a collaboration between teachers of different disciplines and levels to manage and coach multidisciplinary and multilevel projects (Galvin et al. 2007). This type of education is different from traditional methods. It leads to unexpected learning outcomes and is therefore hard to assess. The projects are also quite time-consuming for both teachers and students. But the rewards are tremendous as masses of products and proud students in movies on the web prove.

Pupils: It Kicks

Finally in this entry, we want to suggest reading a little booklet called *Pupils: It kicks* (Hogenbirk, de Rijcke 2006). This gives some examples in Dutch secondary education of new ways of learning with ICT. In the booklet a model is presented which characterizes educational settings along three dimensions. The first one is the axe of the learning context. This varies from theory-based (the subject is the core) to practice-based (applications and practical issues are central). The second dimension is the extent to which the pupils are self-responsible for their learning. It varies from teacher's determination up till the situation where pupils are fully in charge themselves. The third dimension is the pedagogical relationship: from the subject-expert role up till the coaching guiding role.

Conclusive Remarks

It is an understatement to say that there are some challenges to meet when transforming the traditional pedagogical environment into a more self-driven, personalized, and collaborative ICT-supported learning environment. In Hogenbirk (2016) we elaborate on five issues:

- Individual self-responsibility for the learning needs an intrinsic school vision on the position of the learner and the teacher.
- Often the prevailing national curriculum or exam requirements hinder the possibilities for own learner or teacher choices.
- The learning materials and the way ICT is used in such an innovative learning environment have to be tailor-made and adapted for the

specific subjects, for specific groups of pupils, and for the different levels.

- There must be very much attention for teacher training and development because most teachers love to be the expert in their subject and love to demonstrate that; instead here they have to evolve to a more coaching and guiding role, even develop a learning attitude themselves if they are not in charge of the choice of content anymore.
- The final performance of the pupils will be the ultimate determination of the value and validity of these kinds of new teaching and learning arrangements.

Four in Balance, a Model for Actual Development of ICT-Rich Education at School

To help schools to implement the use of ICT, some frameworks and models can be used. In this entry we will explain the so-called “Four in Balance Model” which aims at a balance between school vision, professional development of teachers, digital content, and infrastructure. This model is developed by the research department of Kennisnet, the Dutch National Centre of ICT in Education, and also used to monitor the progress in the use of ICT nationwide (Kennisnet 2015).

Vision of the School

The first pillar in this model is the vision of the school on education in general and the role of ICT to support this vision. We mentioned this in paragraph 2.1 when we were addressing the necessity of acknowledging that an educational environment without attention for ICT and without using ICT is impossible in the era in which we live. In the vision of the school, this acceptance should be the starting point, further elaborated in school-specific objectives for improving the outcome of the education.

How does one look at traditional ways of learning in relation to ICT? How would one use ICT in order to stimulate pupil’s own responsibility for the learning? How is one’s appreciation for using ICT in the balance between “hard” learning outcome,

personal development of the pupils, and the way they should be prepared for further education and future jobs? These are some examples of question to be answered in the school vision.

Professional Development of Teachers

The second pillar in the “Four in Balance Model” is the expertise of the teachers. They should be able to use ICT in their daily practice and in their own professional development. The school management should be aware of the possibilities of ICT and of the ways to support the implementation. The support staff should be able to cope with new developments and an increasing complex infrastructure and be able to use applications and hardware in their classes.

Digital Educational Content

The third pillar of the model is the availability of educational ICT application. In the description in previous paragraphs 2.3, 2.4, and 2.5, we have seen that this is about the use of subject dedicated applications, educational content of the Internet, simulations and educational games, generic software, and the DLE (digital learning environment). However in this model it is not only about the availability of the software but also about the willingness of the school to provide licenses, to maintain the software, to instruct the teachers, to provide the financial means to maintain the applications, and to provide user support.

ICT Infrastructure

The fourth pillar in the model is the infrastructure, dealing with hardware, networks and connectivity, smartboards, mobile smart phones, technical support, etc. In this domain the debate is going on if BYOD (bring your own device) is a proper development: if you can allow, or even expect or demand, that pupils use ICT devices which they bought themselves and if you can ask the teachers to be familiar with a variety of hardware in their classes. Some schools developed the CYOD concept: let the pupils choose their device from different possibilities. Of course a school could also provide the equipment for a 1:1 situation (one device for every pupil), but most schools are financially not capable to afford that luxury.

In 2012 an important extra layer was added to the model: the four pillars should not only support the primary process of the teaching and learning but also the secondary processes of organizing and managing the educational practice in schools and accounting for the outcome.

Conclusive Remarks

The “Four in Balance Model” states in principle that four pillars should be relatively balanced to each other. If a school has a perfect infrastructure, but the teachers do not know how to use the ICT, the implementation fails. If the vision is providing a clear direction for using ICT, but there is no suitable software available, successful ICT usage will not take place.

The model can illustrate two ways of working toward a more ICT-rich school environment. The one way that failed was that many schools (and national projects) started in the past with providing infrastructure and some dedicated educational courseware. At the same time these provisions were not accompanied by teacher training and were not attached to the school vision. The result was that most often the implementation failed.

More successful is that nowadays many schools formulate a vision on ICT use at first (there are much more clear images of effective and useful use of ICT), take care of sufficient knowledge and skills of the teachers, and in parallel decide which software and hardware are needed to translate the vision into practical learning activities.

So the model provides a powerful thinking frame for the actual implementation of ICT in a specific school. Schools can evaluate themselves to what extent they are fulfilling the right conditions, in balance, on all of these aspects, in relation to the phase described in Chapter 2 in this document.

The P2V Framework for ICT Implementation

In 2009 the inspectorates of the Netherlands, France, Spain, Scotland, Sweden, and Lithuania

finalized within the P2V project the European Framework for the Evaluation of ICT in Education. This framework can be used to assess a school on their level of development on ICT (van Oel et al. 2009). The framework consists of eight domains with several quality indicators in each domain.

In brief: The first domain is about leadership: Is there a vision and a strategy for implementation? The second domain concerns the infrastructure and access: Are these sufficient, suitable for the needs of the school, stable, and efficient? The third domain is about the curriculum planning: Is it coherent, balanced, and consistent? Does the curriculum meet the national requirements? The fourth domain is quality assurance and improvement: Is a cycle of quality control, evaluation, and revision used? Very important is the fifth domain: How and to what extent are the pupils using the ICT and capable of doing that? The sixth domain is the teaching process and teaching staff competence. The seventh domain concerns administrative use. The last domain is about the impact on learning and effects of ICT use on pupil attainment. This framework can be used to assess the ICT development of one particular school, either by an external body (i.e., an inspectorate) or by the school itself through a self-evaluation.

Example of Using the P2V Framework in a School

An example of a self-assessment of the implementation of ICT in a school is given in a series of papers on ICT Action School Development at Helen Parkhurst Dalton School in the Netherlands (Hogenbirk and Braak 2008, 2009, 2011). In September 2007 an assessment on ICT in education took place at this school through a visit of a group of inspectors, by using the European P2V framework. The results of this assessment were extensively described in the first paper mentioned above. We present here as an example only the assessment of the indicators within the framework in the first visit (2007) and at the state of the last self-evaluation (2011). See Table 1.

In this example one can see progress but also decline. For the management of the school and

Implementation of ICT in Secondary Schools, Table 1 ICT self-assessment September 2007 and February 2011, indicators for ICT quality

Leadership	Score 2007	Score 2011
C1.1 There is a clear vision for the use of ICT	0 1 2 3 4	0 1 2 3 4
C1.2 There is a strategy to realize the vision	0 1 2 3 4	0 1 2 3 4
Infrastructure and access	Score 2007	Score 2011
C2.1 The available resources reflect the needs and vision of the school	0 1 2 3 4	0 1 2 3 4
C2.2 The deployment of ICT resources enables efficient use of them	0 1 2 3 4	0 1 2 3 4
C2.3 Support systems optimize the use of ICT	0 1 2 3 4	0 1 2 3 4
Curriculum planning	Score 2007	Score 2011
C3.1 Meeting local, regional and national requirements	0 1 2 3 4	0 1 2 3 4
C3.2 Coherence, balance and consistency	0 1 2 3 4	0 1 2 3 4
C3.3 New developments in ICT and pedagogy	0 1 2 3 4	0 1 2 3 4
Quality assurance and improvement	Score 2007	Score 2011
C4.1 Review and self-evaluation of ICT policy and practice	0 1 2 3 4	0 1 2 3 4
C4.2 Action planning and implementation	0 1 2 3 4	0 1 2 3 4
C4.3 Action monitoring and revision	0 1 2 3 4	0 1 2 3 4
Pupil use	Score 2007	Score 2011
U1.1 Development of ICT skills	0 1 2 3 4	0 1 2 3 4
U1.2 Enhancement of learning	0 1 2 3 4	0 1 2 3 4
The teaching process	Score 2007	Score 2011
U2.1 Developing pupils' ICT capabilities	0 1 2 3 4	0 1 2 3 4
U2.2 Use of ICT to enhance teaching	0 1 2 3 4	0 1 2 3 4
U2.3 Teaching staff competence and confidence	0 1 2 3 4	0 1 2 3 4
Administrative use	Score 2007	Score 2011
U3.1 Identifying issues impacting learning and teaching	0 1 2 3 4	0 1 2 3 4
U3.2 Communication is supported.	0 1 2 3 4	0 1 2 3 4
Impact on learning and standards	Score 2007	Score 2011
O1.1 Gains in broad learner achievement	0 1 2 3 4	0 1 2 3 4
O1.2 Effects of ICT use on pupil attainment	0 1 2 3 4	0 1 2 3 4

The indicators are assessed with the values 0 or 1 to 4. Their meaning is as follows:

0 no evidence available or not relevant

1 bad, there is hardly any positive evidence for a particular indicator

2 insufficient, there is not enough positive evidence for a particular indicator

3 sufficient, there is enough positive evidence for a particular indicator but improvement is possible

4 good, most or all evidence for a particular indicator is positive

for the people responsible for different aspects of ICT, this way of looking at your self is very valuable. It leads to debate and discussion about the causes for the assessment of the indicators and about the ways to move forward.

Conclusive Remarks

The five phases in the "Four in Balance Model," and the P2V framework are different ways to look at the implementation process in a secondary school. The first one is more or less a tool to provide insight on a bird's eye level to management and teachers of a school in the

phase of development of the school with respect to ICT.

By using the "Four in Balance Model," schools become aware of the relation between different key issues which play a role in the usage of ICT.

By using the P2V framework as a self-assessment, one can really mark the development of the school in terms of level of performance.

At different times and in different constructs, one can use one of the models to improve the implementation process. We hope that the presented models are useful to guide that process.

Cross-References

- [Computers in Secondary Schools, Educational Games](#)
- [Modeling the Process of Information Technology Innovation in Education](#)
- [Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools](#)
- [Teaching and Learning Computational Thinking and Coding Skills](#)

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Inclusive Education

► [IT on Teaching and Learning Process of Visually Impaired Students](#)

Indications for Kinesthetic Learning Through Haptic Devices

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Synonyms

[Anatomy learning](#); [Dentistry](#); [Dexterity](#); [Haptic interface](#); [Learning resource](#); [Phantom omni](#)

Introduction

Haptic technology can provide a sense of touch, either by force feedback or by different vibrations, to give different sensations to the user. It can be used in conjunction with 3D virtual reality or augmented reality environments to give improved perceptions of reality with the additional sensation of touch. This type of haptic enhanced interface can provide a sense of reality in different domains, such as 3D painting, brush-based models,

calligraphy, dentistry, or training and learning in different subject fields (Perry et al. 2017; Shenoy and Shenoy 2013). There are a number of studies on the learning effectiveness of haptic systems which report how a greater sense of immersion in a learning environment can promote deep conceptual learning for difficult concepts. Haptic feedback can assist the development of fine motor skill performance in dentistry (Perry et al. 2017) and in other medical areas.

Shaikh and his colleagues proved their students' improved conceptual understanding with haptic-enabled learning experiences (Shaikh et al. 2017). An adjunct simulator with haptic feedback was used to develop the clinical skill of nasogastric tube placement from patient's nostril to the stomach for feeding or drainage. This proved an effective method of education and training for nursing students and medical students (Chiang et al. 2017).

Calligraphy is another area where the haptic interface has been tried, since Chinese calligraphy needs a unique way of controlling the strength of strokes. Force feedback may enhance the achievement of a different type of learners. It may be more beneficial to kinesthetic learners with this preference of the visual, aural, reading/writing, or kinesthetic (VARK) sensory modalities. A Chinese calligraphy system and its effectiveness with children and adults were examined (Narita and Matsumaru 2015).

Earlier research reported that haptic guidance also improves learning outcomes related to handwriting motor skills. New findings were additionally reported that performance was significantly improved whether it was with full or partial haptic guidance (Teranishi et al. 2017).

As technology develops, various new learning resources with haptic feedback, in particular, become available for use. The Learning Anatomy with Haptic Feedback System (LAHFS) is one such new resource. It was developed to give haptic feedback from virtual organs in human anatomy classes (Yeom et al. 2013). This relatively new resource may help learners access anatomical specimens outside limited clinical settings, thus expanding study opportunities (Chuttur 2009; Craig et al. 2010).

It is interesting to investigate what factors influence student acceptance of such a novel resource, if there are any. For example, how a learner reacts may vary according to their gender, preferred learning style, or previous experience with a similar type of resource. Students of different genders may accept different models and media differently. Other considerations include olfactory and video media, the effect of multisensory of visual and tactile modalities, gender differences in learning style preferences among undergraduate physiology students, and many more.

Multimodal deep learning has improved achievement compared to unimodal learning (AlKhasawneh 2013). To understand the preferred sensory modality of students for learning anatomy, consenting students were administered a printed form of version 7.2 of the VARK questionnaire. The VARK instrument is only one of many to measure student learning styles or preferences (Coffield et al. 2004), and some have questioned the value of learning styles. However, opportunities to assess kinesthetic learning in higher education are rare, and the main research question was to measure the level of acceptance of the haptic device as a tool.

Haptic sensory learning resources for dental learning or surgical training have been used (Ullrich and Kuhlen 2012) with 79% of students benefiting from the study as kinesthetic learners. This led us to investigate if the haptic sensory learning resource would have a similar effect in anatomy learning, at least for kinesthetic learners.

Problem-based learning (PBL) can be used with the different learning styles (Almigbal 2015) to investigate the learning outcome according to the preferred learning styles of learners.

Design Research Paradigm

The design research paradigm is one of common approaches for collecting data from users in a cyclic manner. This cyclic approach is useful to find an appropriate model and users' acceptance of a system through different versions at different

stages. The design research paradigm was adopted to assess acceptance of the haptic-anatomy system. The Learning Anatomy with Haptic Feedback System (LAHFS) was developed using the software development life cycle over three stages (Fig. 1). The system evolved as the user tests were performed in a cyclic manner.

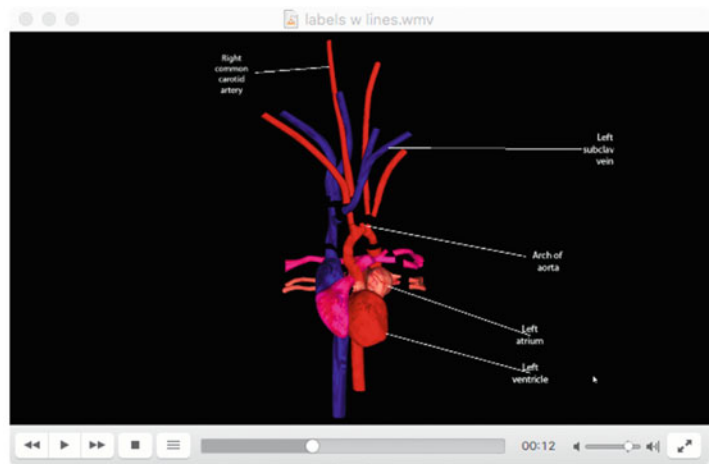
The technology acceptance model (TAM) (Davis et al. 1989) was the basis for the acceptance questionnaire. TAM posits that usage of technology is influenced by perceived usefulness and ease of use (Chuttur 2009; Marangunić and Granić 2015).

Later, variant branches came out of the original technology acceptance model from Fred Davis, leading to the theory of reasonable action (TRA) and the theory of planned behavior (TPB) with many extensions or modifications in the technology acceptance field. Haptic enabling technology and TAM is another branch of TRA/TPB focusing more with haptic technology (Oh and Yoon 2014).

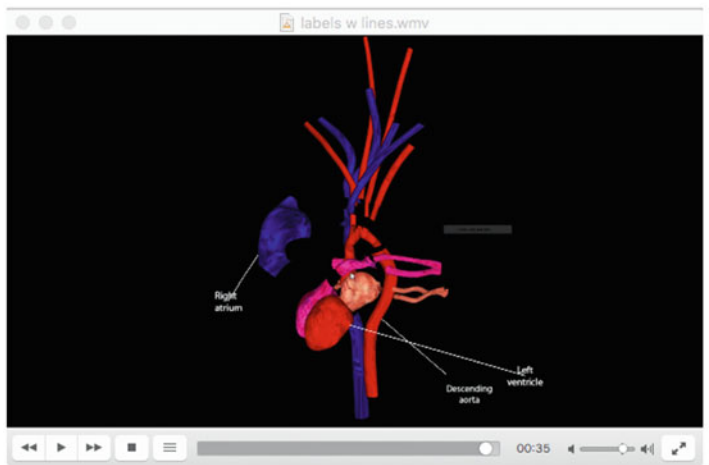
Ease of use and usefulness were the two important factors used to measure if the users will accept the system in this TAM-based study. TAM used a few questions to collect the data. These two main elements are used to measure the acceptance of technology by users. Each element of acceptance was measured based on ease of use and usefulness; then the acceptance was analyzed with respect to other variables such as gender, prior experience, personal preferred learning styles, and their enrolled courses.

For this project, data was gathered from participants in three distinct ways. A postexperience survey using a visual analogue scale (the "VAS questions") was administered to each participant to gather their perceptions of the haptic device linked to the 3D display. This survey provided much of the information required by the TAM theory. The focus to discuss here is how the system was accepted, based on student gender, preferred learning style, and their prior experiences with any similar sort of interface. The main questions to measure the users' acceptance were "was it easy to use the system?", "was the system useful?", and "would you recommend the system to the university to adopt?" as they are three important points from TAM. A visual analogue scale

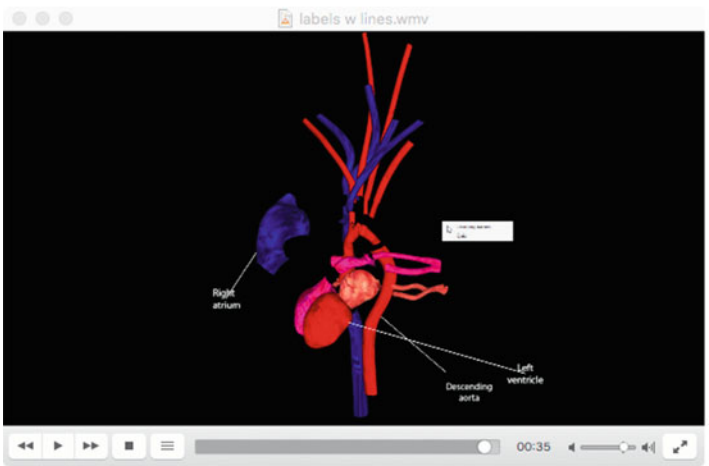
Indications for Kinesthetic Learning Through Haptic Devices, Fig. 1 LAHFS (a) starting, (b) rotating and disassembling, (c) floating option of other menus, e.g., quizzes



(a)



(b)



(c)

(VAS) was used in the survey to measure the level of agreement to a statement between 0 and 100. The second method of gathering data was through optional quizzes which participants could choose to activate during their LAHFS session. These quizzes gave feedback on anatomical learning achievement and comprised pop-up randomized questions with randomized answers. Finally, the VARK questionnaire was also administered to some users after the LAHFS session to identify the learning modality they most preferred.

The haptic-anatomy system was developed with the Phantom Omni (Yeom et al. 2013). A force-feedback pen was gripped by the user, who saw anatomical organs on a screen to learn to identify human internal organs and associated medical nomenclature (Yeom et al. 2013). When any part of each organ was held and moved around, it allowed the user to examine the selected organ with 360° of perspective (Fig. 2). Also, the user felt different haptic feedback depending on the hardness/rigidity and texture of the organ. Thus, pushing into a liver met gentle resistance, but tapping a rib encountered very hard opposition. The three development versions were tested by three different user groups.

The user groups were from 3 different cohorts with 89 participants including 58 males and 31 females with average age of 20 years old as the system developed further at each cycle according to the design research paradigm. The courses that the users were enrolled in were mainly Bachelor of Medicine/Bachelor of Surgery (MBBS), Bachelor of Education (Health and Physical Education and Outdoor Education), Bachelor of Exercise Science, and Bachelor of Human Movement. Bachelor of Computing students participated in user test.

The first user test was done with second-year students, but the other two user tests were done with first-year students. Hence our assumption was made that no preknowledge was present. The VAS survey questions asked if the user performed well with the system, if the system was useful, if it was easy to use, if the user was physically stressed or mentally stressed, if the user would recommend the school to adopt the system as a learning resource, and if the optional quiz was useful.

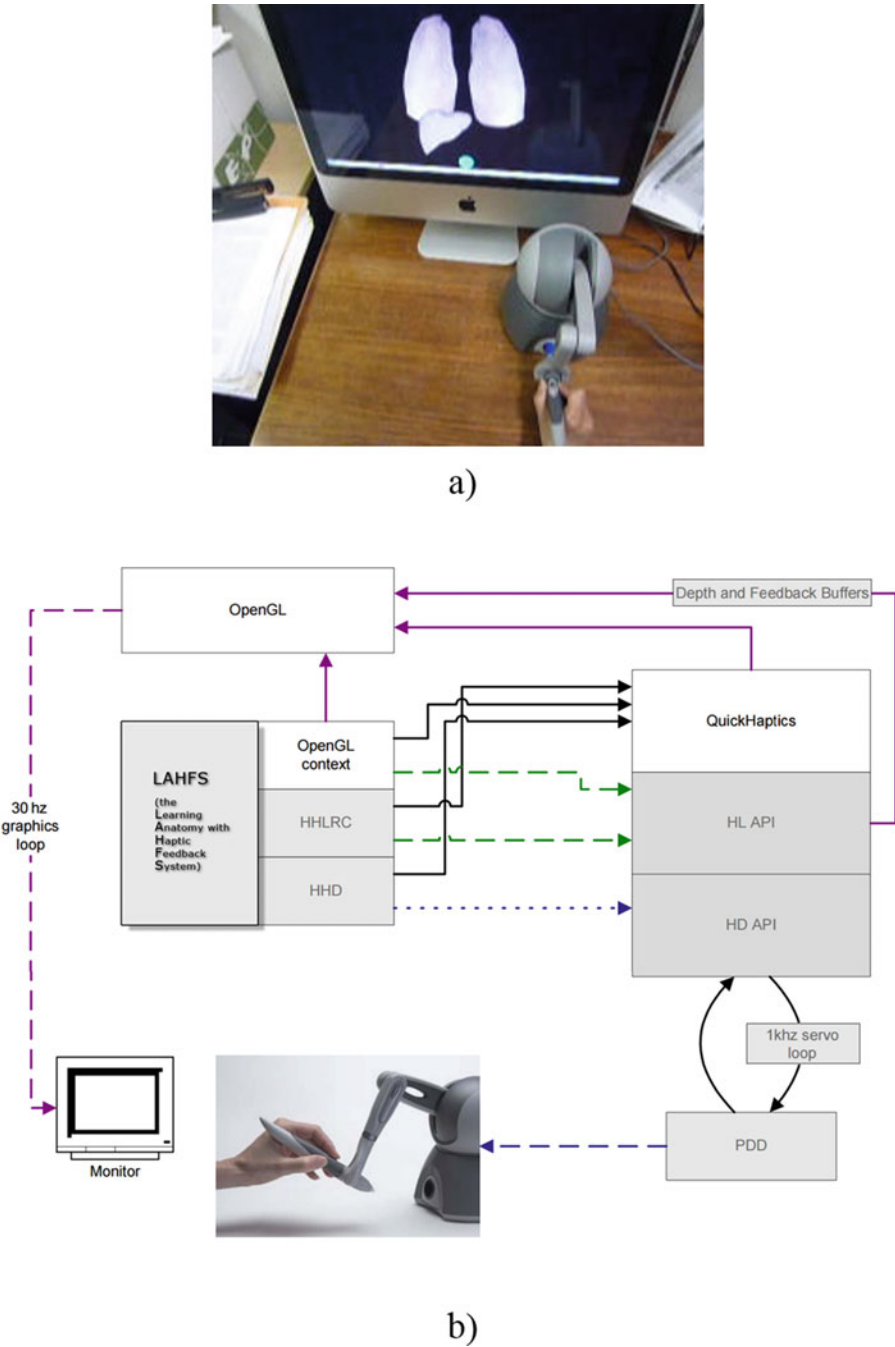
Analysis of Preferred Learning Style

The VARK questionnaire was used to find out each participant's preferred learning style(s) out of different available measurements. Some researchers argued about the validity of learning styles, yet many students believe the conventional wisdom that learning styles are legitimate and adopt it outside of class study.

The VARK model classifies learners based on the sensory modality in which they prefer to have information presented to them. The individual categories are: Visual (V): if learners prefer (prefer or absorb information more effectively when it is presented in a visual form. Auditory (A): if learners prefer to hear information being presented to them such as attending classes, discussing the materials with others, and reading notes or text out loud. Reading/Writing (R): learners prefer to see new information in writing via text or tables. Kinesthetic (K): learners prefer new information to be clearly relevant to the real world or something that they can manipulate with their hands. Hands-on practices and real-life examples are recommended. Also, this model categorizes the learner as bimodal, trimodal, or quadrimodal depending on how many preferences each student has.

As assessed by the VARK questionnaire, further information was sought if their preferred learning modality had any influence on their ratings of the LAHFS system, system version 3. Participants' responses were correlated to the VAS questions and their learning achievement quiz results with their scores on the VARK questionnaire.

The percentage of visual (V), aural (A), read/write (R), and kinesthetic (K) options chosen out of the total number of options selected was based on a relatively small population of the study. The percentages of different options by each participant were V 23% $\pm$ 10 (24%), A 25% $\pm$ 12 (24%), R 22% $\pm$ 9 (21%), and K 29% $\pm$ 13 (28%), with all approximately normally distributed among $n = 43$ system v3 participants who completed the VARK questionnaire (Shapiro-Wilk tests of normality $p = 0.078$ to 0.288). These percentages are similar to those reported



Indications for Kinesthetic Learning Through Haptic Devices, Fig. 2 (a) User environment, (b) system structure

on the VARK website, based on 74,932 respondents from January to March 2015, V 21.7%, A 24.6%, R 24.9%, and K 28.8%, as well as for those in medical fields (13,181 respondents), V

22.0%, A 24.3%, R 24.9%, and K 28.8% (Oh and Yoon 2014).
Pearson's correlations (r) of percentage V, A, R, and K with the five VAS questions are shown in

Indications for Kinesthetic Learning Through Haptic Devices, Table 1 Correlations $r > 0.1^{(1)}$ and $r < -0.1^{(2)}$

	Performed well	System useful	Easy to use	Mentally stressed	Physically stressed
V %	-0.005	0.131 ⁽¹⁾	-0.021	-0.098	-0.041
A %	-0.151 ⁽²⁾	-0.173 ⁽²⁾	-0.115 ⁽²⁾	-0.008	-0.111 ⁽²⁾
R %	-0.123 ⁽²⁾	0.037	-0.005	-0.039	-0.024
K %	0.232 ⁽¹⁾	0.027	0.127 ⁽¹⁾	0.114 ⁽¹⁾	0.149 ⁽¹⁾

Indications for Kinesthetic Learning Through Haptic Devices, Table 2 Correlations $r > 0.1^{(1)}$ and $r < -0.1^{(2)}$

	Would recommend	Quiz useful	Quiz result
V %	0.018	0.197 ⁽¹⁾	-0.107 ⁽²⁾
A %	-0.163 ⁽²⁾	-0.272 ⁽²⁾	-0.103 ⁽²⁾
R %	0.010	-0.100 ⁽²⁾	-0.015
K %	0.128 ⁽¹⁾	0.165 ⁽¹⁾	0.194 ⁽¹⁾

Table 1. None of these correlations were statistically significant. Interestingly, only “kinesthetic” positively correlated with performed well ($p = 0.135$) and easy to use ($p = 0.418$) but also with mentally stressed ($p = 0.468$) and physically stressed ($p = 0.339$).

Table 1 presents correlations (Pearson’s r) between VARK learning style percentages and VAS questions.

Similarly, there were weak positive but nonsignificant correlations of “kinesthetic” with “would recommend to university,” “quiz useful,” and quiz results ($p = 0.413$, 0.290 , and 0.217 , respectively). “Visual” learners also weakly but nonsignificantly positively correlated with finding the “system useful” and “quiz useful” ($p = 0.403$ and 0.214 , respectively).

Table 2 presents correlations (Pearson’s r) between VARK learning style percentages and VAS questions as well as quiz results.

One of the most popular areas of applying the haptic technique is in training or learning fields or with simulations.

A randomly generated quiz from the question bank was attempted by each student. When their answer was incorrect, they were given another chance to answer the question. This was because j holding the pen and trying the different system may impact performance, although each user spent about 10–15 min with the haptic learning modules beforehand.

The optional achievement quizzes were used by 46 students in total. The test size was small, but

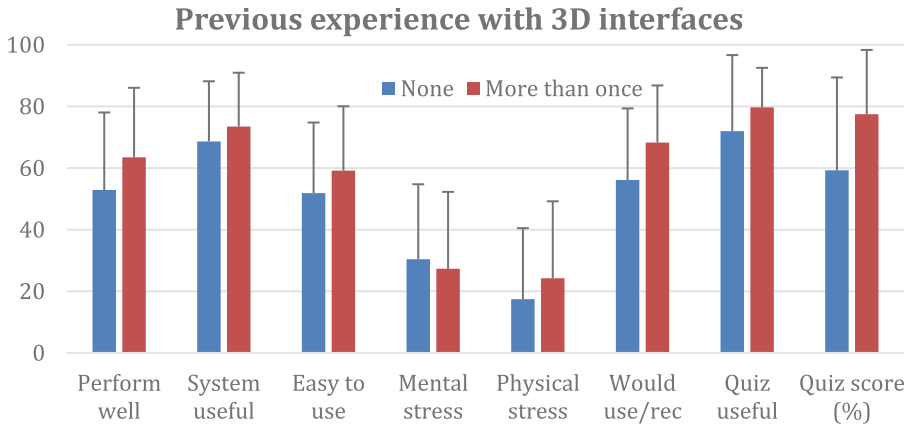
the results indicated the interface was easy enough to be adopted (or easy to use). The mean quiz results from students of each of the different learning modalities were V (58.75%), A (66.36%), R (82.50%), K (80.71), and multi with K (65%). Thus, visual learners did not achieve greatly with the system, but read/writing and kinesthetic learners performed well.

Previous 3D Experience

Quite a number of students identified themselves as having prior experience with 3D interfaces ($n = 63$), whereas very few users had used haptic interfaces before ($n = 15$). Users with prior experience of 3D interfaces were more likely to assess the system positively (Fig. 3). The item, “would you recommend,” was significantly different as $p = 0.025$ from t-test between two groups with and without previous 3D interface experience. The post-activity quiz score gave $p = 0.050$ with Mann-Whitney U test, showing another significant difference. Therefore, the study concluded previous experience with a 3D interface made users more likely to accept the haptic learning resource.

Conclusion

In such an important and difficult subject as anatomy, a new type of learning resource could well



Indications for Kinesthetic Learning Through Haptic Devices, Fig. 3 Responses with/without prior 3D experiences

help students. The availability of different resources, including a haptic system, can assist students who learn differently.

No significant difference was found in learning achievement between students with different learning styles. This means the haptic system works for all different styles of learners; at the same time, it doesn't have any particular benefit to kinesthetic learners.

However, significant differences were found with prior users of 3D models. They assessed the system as "performed well." Their quiz results were higher than for students without previous 3D experiences. When users had previous experiences with 3D systems, they gave more positive responses and achieved higher quiz results; however, these experienced users found the system more physically stressful. One thing to clarify was if the users were talking about the same level of 3D experience. Most of them were talking about 3D images of games and other applications, unlike 3D models which can be manipulated in the LAHFS system.

Gender differences were not found in this experiment, unlike most of the literature. This could mean that the haptic system is gender neutral. However, the population for comparison was rather small (under 100 students).

More recently, this result has been independently confirmed and reported, showing that conceptual knowledge showed significant knowledge gains, but there were no significant differences

between the haptic and non-haptic condition (VARK Learn Limited 2016).

Simulations are being developed with skin mechanisms and tactile nerve fibers to fill the gap of current systems to convey sensory information with multiple fingers (Saal et al. 2017).

Also, various tactile-haptic methods are being trialed to enhance accuracy in learning, for example, with shape recognition, basic piano education, or surgical training (Lee et al. 2017; Pinzon et al. 2017; Pala and Mihci Turker 2019).

In a future, the system will let students explore each anatomical object with their whole hand rather than just a single haptic touch point. This will be more natural for users and will incorporate tactile (touch sensations) as well as force feedback. As haptic technology develops rapidly, such new devices will add to the kinesthetic learning experience of the haptic-anatomy system (Webb et al. 2019).

Cross-References

- [Computational Thinking](#)
- [Computers and Educational Improvement](#)
- [Computing Education, Outcomes of](#)
- [Methodological Quality of Educational Technology Meta-analyses](#)
- [Technologies in Mathematics Education](#)
- [Technology Enhanced Learning](#)

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Indigenous

- Safe Frames, Essential Determinant for Educational Technology Implementation in an Indigenous Context

Indigenous Literacies

- Digital Technologies and Literacy Contexts for Young Indigenous Children

Industrial Revolution 4.0

- Science Education and Technology

Informatics

- Computing Education, Outcomes of

Informatics in Secondary Education

► Implementation of ICT in Secondary Schools

Information

► Information and Communication Technologies in Chilean Schools, from Enlaces to the Present Day

Information and Communication Technologies

► Computing Education, Outcomes of

Information and Communication Technologies in Chilean Schools, from Enlaces to the Present Day

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Synonyms

Education; Equity; History; Implementation; Information; Policy; Program; Reforms; Teaching; Technology

Introduction

The use of information and communication technologies (ICT) in education has, for a while now, generated extensive interest as well as being attributed to have an important role in education. Therefore, the introduction of ICTs in education is no longer a new concept, at least in industrialized and developing countries. However, the path

taken by those that decide to introduce ICTs in education vary and so does the reasoning. Chile's journey was in itself unique given that prior to 1990, Chile had minimal exposure to ICTs in education, that is, no massification of ICTs in primary and secondary levels of education. There was of course, well before the 1990s, a limited exposure to computers at higher education levels. In fact, since 1968, courses were offered by the four main universities in computer programming. On the other hand, at the business level, computers had made a limited presence. However, for a short period in the early 1970s, the government approved a novel cybernetic project that was to be short lived as a result of a military *coup d'état*. With the return of democracy, the newly elected government was interested in making changes to an ailing education sector and the need for reform was palpable.

The newly elected government had identified that Chile's education system had structural deficiencies, poor performance results, impoverished schools, and lacking in quality and equity. Thus, ICTs were seen as tools that would enrich the students' education and ultimately provide a better quality of education under a more egalitarian system. The broader reforms were centered on the regulatory frameworks, changes to curriculum (to both, primary and secondary levels), teacher training and development, increasing pedagogical resources and infrastructure for schools, improving students' attendance, and increasing the time spent on teaching. However, the introduction of ICTs into the education system and the reforms has not been without challenges and/or criticism.

This journey of reforms started in 1992 with the birth of "Programa Enlaces" or "Enlaces" for short. A pilot program that was meant to interconnect a small number of schools in the capital Santiago and which later expanded to include the region of Araucania located about 650 km to the south of Santiago.

Enlaces was primarily an educational web that connected schools and provided access to ICTs. But Enlaces expanded quickly and by 1995, over 5000 schools had been connected. By the year 2000, Enlaces was further expanded and managed to connect the totality of rural schools in the

country. Enlaces was also enhanced by other initiatives that placed more ICTs in the classroom, introduced teacher training in the use of ICTS, connected rural school with improved bandwidth, increased the number of student scholarships that provided free laptops or computers, and the creation of educational software and portals. To this day, new programs have been spawned from within Enlaces such as the “Me Conecto para Aprender” program created in 2015, which is still operational and that gives all year seven student enrolled in public schools, a free personal computer.

Preamble to Massification and a Novel Project of Cybernetics

Computers had entered the Chilean business environment as early as May 1961 when the first IBM-1401 was acquired to be used by Customs in the port city of Valparaíso, followed by the Treasury, the Air Force, and a mining company some years later (Ojeda et al. 2019). By then, universities had become aware of the use of computers and so between 1963 and 1966, the main universities at the time had acquired computers, namely, the Catholic University, Santa María University, and the University of Concepción obtained IBM-1620 computers (Ojeda et al. 2019). Also, between this period in 1964, the State Technical University (nowadays, known as Universidad de Santiago de Chile or USACH for short) receives as a donation a Datatron computer (Ojeda et al. 2019). Throughout this period, computers, which required a sizeable capital outlay, space, and know-how, were mainly the domain of big business, government bodies, and some universities. However, during Allende’s government, which lasted from 1970 to 1973, there was a bigger vision on how computers could be used, and in 1971, the government started to develop a cybernetic system for the management and transference of information (Ojeda et al. 2019). The project had been approved by the President and was known as Cybersyn (Ojeda et al. 2019). It was envisaged that Cybersyn would enable real-time economic information on the state-owned enterprises

(Espinosa and Walker 2011; Ojeda et al. 2019; Pickering 2004). In charge of the project was Fernando Flores, who had been appointed as the technical director of the state development corporation known as CORFO and who was aware of the solutions and theories of the British Stafford Beer, known for his work on *management cybernetics* and the Viable System Model (VSM) (Ojeda et al. 2019; Pickering 2004). Management cybernetics is best described as:

the concrete application of natural cybernetic laws to all type of organisations and institutions created by human beings and to interactions with and within them. (Cwarel Isaf Institute 1989, online)

Beer’s VSM was a diagnostic tool that enabled the studying of organizations while focusing resources and relationships required to support an organization’s viability rather than concentrating on its formal structure (Espejo et al. 1999; Pickering 2004).

Beer was invited to Chile to help in the design and implementation of a control system that would comprise and model the entire economy (Espinosa and Walker 2011; Ojeda et al. 2019) and in the short time, from 1971 to 1973 (Ojeda et al. 2019; Pickering 2004) that the project Cybersyn was in its inception phase, it succeeded in modelling the whole of the social economy, including the design of performance indicators, developing of the necessary information systems and decision-making means (Espinosa and Walker 2011). However, the project came to an abrupt end when the military coup led by Pinochet deposed President Allende on September 11, 1973, and so, it was the end of one of the most advanced cybernetic and political projects of its time (Espinosa and Walker 2011; Ojeda et al. 2019; Pickering 2004) and one can only speculate where it would have led to in terms of its purpose, possible expansion, demand for trained personnel, and the education sector both as an adopter and or enabler.

Return to Democracy and the Birth of Enlaces

Mr. Patricio Alwyn became the first president of Chile after the Pinochet dictatorship had ended

and democracy was once again restored (Bauer 2017), Mr. Alwyn's presidency spanned from 1990 to 1994. Prior to 1990, Chile had no public policy to promote the massification and use of ICTs in education and its exposure in this area was rather limited (Jara 2013). Although, there was a small number of schools which either had computers or a lab, these were mainly secondary schools where the aim was to teach programming, for example, languages such as Basic or Logo (Jara 2013). At the academic level, Jara (2013) indicates that there was an incipient and interested community on this theme. However, in March 1990, a program known in Spanish as the "Programa de Mejoramiento de la Calidad y Equidad de la Educación Básica" (usually referred to as "MECE Basica") was conceived (Jara 2013; Toro 2010) and would later have an impact on how ICTs were perceived, which led to a massification of ICTs in schools.

The new authorities recognized that changes were necessary in the education system due to the failures of the inherited system which had been through a period of decentralization and privatization during the Pinochet dictatorship (Planas 2011; Sánchez et al. 2011; Toro 2014, 2018). There was also a consensus that as a result of the challenges posed by the *how-to*, *to form*, *to educate*, and *to learn* in a world where information is the central element of productivity, where individual and collective opportunities are played out within the networks that are accessible (Bellei 2010). Thus, President Alwyn's newly elected government wanted to respond to these challenges and so, the year 1992 saw the creation of "Programa Enlaces," often referred to "Red Enlaces" or only as "Enlaces" ("Linkages Program" in English). The project was born within the MECE Basica initiative (Claro et al. 2012; Enlaces 2019c; Sánchez and Salinas 2008; Silva and Figueroa 2002; Toro and Tatnall 2016; Toro 2010).

With finance and advice from the World Bank, the initiative got underway in 1992 connecting 12 schools in the capital, Santiago then expanding to Araucania, some 600 km to the south of capital

and covering 100 schools in this region (Colaboradores de Wikipedia 2019; Enlaces 2019c). And so, the country embarked on a national initiative to create a national educational network of primary and secondary schools with the objectives of introducing ICTs in schools, enriching the curriculum, giving students equal opportunities to access ICTs (Enlaces 2019c), in short, to improve quality, equity, and efficiency (Holm-Nielsen et al. 2004). Thus, as argued by Bellei (2010), Enlaces is a public policy in which the government has been the promoter of technical innovation, ultimately getting the new generations closer to ICTs (Bellei 2010).

The "Enlaces" program was developed as an experimental initiative to implement computer technology in schools (Claro et al. 2012; Sánchez and Salinas 2008). The inception of Enlaces was not straight forward as the then Minister of Education, Mr. Ricardo Lagos had to contend with two main approaches, each with their pros and cons (Toro 2010). One approach intended to follow a similar path as taken by Costa Rica, with emphasis on the learning of specific programming languages and requiring massification which would require a high number of computers installed throughout the country (Jara 2013; Toro 2010). According to Toro (2010), this approach was met with questions on acceptance, adoption, quantifiable result, and obsolescence. Notwithstanding, this was a highly visible approach politically, but it was not adopted. Therefore, a second proposition was considered, one that was much less visible politically, but which has been in the long term generally seen as a public policy in which the state has been the biggest promoter of technological innovation (Bellei 2010). The second option was Enlaces, a pilot program with a much smaller presence and that would lay the foundations for a much bigger future project (Jara 2013). The year 1992 also saw the creation of a software program known as "La Plaza" (in English, town square) which was developed to facilitate the use of the computers by teachers and students alike using the metaphor of the town square as a meeting place (Enlaces 2019c).

The Road to Introducing ICTs in Chile's Schools

In 1993, Enlaces was primarily involved in making the program widely visible by holding expos throughout the length of the county whereby, teachers and students presented samples of their successful adoption and use of ICTs in the curriculum.

Enlaces expanded quickly and defying expectations, by 1995 a total of 5300 schools (ranging from primary to secondary levels) had been connected and that also included Easter Island and Antarctica (Enlaces 2019f). This meant that about 2.5 million students from primary to high school had access to ICT resources provided by Enlaces (Enlaces 2019f). However, the majority of rural schools had to wait another 5 years to start connecting to Enlaces (Jara 2013, Enlaces 2019g). The same year, a web site was created under the domain of “enlaces.cl” that used the Mosaic browser and which contained educational material (Enlaces 2019f).

In 1996, an alliance was formed between the Ministry of Education and the universities along the entire county (Enlaces 2019b), and this was known as the “Red de Asistencia Técnica de Enlaces” but usually referred by its initials as RATE (Enlaces 2019b; Jara 2013). The aim of RATE was to support the primary and secondary school that were part or pending connection to Enlaces, becoming an integral component to the expansion of Enlaces throughout the country (Toro 2010; Jara 2013). Initially, this alliance comprised 6 universities and later expanded to 24, out of which, 7 had a leading role in the implementation of Enlaces to the rest of the schools in the country (Jara 2013). The universities which were part of RATE were involved in providing the school teachers with ICT training, as well as, technical support, email services, and to keep up with the growing demand due to the rapid expansion, the universities also organized a network of about 1000 trainers who were usually school teachers who originated from the schools already connected and who served as Enlaces’

coordinators who helped to create a nexus between the school and university frameworks (Hinojosa et al. 2009; Toro 2010; Jara 2013; Enlaces 2019b).

In 1998, the educational reform officially incorporated Information Technology as a curriculum subject for high schools (Enlaces 2019h). Also, for 4 consecutive years, that is, 1998, 1999, 2000, and 2001, CDs containing educational resources and tools such as software, catalogues, and search engines were distributed to schools (Enlaces 2019h). Most importantly, the Internet arrives free of charge to the schools with the help of private enterprises such as Telefonica CTC Chile with connecting speeds of 64 kbps (Enlaces 2019h).

The year 1999 saw the creation of a manual which was provided to all schools and that intended to support the learning of the Internet and its services and to assist in the incorporation of the Internet as a pedagogical tool (Enlaces 2019i). Information technology is in its second year as a subject in high schools.

The year 2000 marks an important point for Enlaces due to its expansion of coverage which would connect rural and remote schools (Enlaces 2019g; Hinojosa et al. 2009); the same year, a catalogue of educational software was created to increase and provide newer educational tools (Enlaces 2019g). This was followed in 2001 by the creation of the Portal EducarChile to complement the other resources already available (Enlaces 2019j; Oteiza and Miranda 2010). At the same time, more software was developed. This time, it was designed to complement the teaching and learning of language and communication (Enlaces 2019j).

In 2002, Enlaces is recognized with an equity award at the Second Information Technology in Education (SITE) conference held in Nashville, USA, for increasing the digital equity and the renovation of education through the use of ICTs (Enlaces 2019k). During this period, teachers were also situated at the vanguard of the integration process (Enlaces 2019k). However, the government also pushed to increase and or bring

digital alphabetization to the wider population and so, those schools that had computer labs would open them to enable the training of those who wished to take part from the local community (Enlaces 2019k).

During 2003 and 2004, there were further resources made available such as digital classes, refurbished computers placed in classrooms (approximately 30 students per computer), improving the performance in Mathematics using ICTs, but most importantly, a study conducted by the “Universidad Catolica” University concluded that a significant number of teachers were using ICTs and it also indicated that 90% of teachers were using the internet to access educational resources such the EducarChile portal, more than twice a week (Enlaces 2019l). The rest of 2004 saw a further rollout of Internet access to remote rural schools (Enlaces 2019l).

In 2005, the Ministry of Education creates the Enlaces Centre of Education and Technology as recognition that technologies could provide a tangible support role in the school learning process (Enlaces 2019m). Moreover, the Centre’s objective was to be a point of reference and initiator of public policy related to educational technology and the digital alphabetization of the general population (Enlaces 2019m). During this period, a system of certification was introduced so that students could prove their competency in ICTs (Enlaces 2019m). The year 2005 also saw the creation Edulinux, this was a Linux-based solution that provided an alternative open source that extended the life of some obsolete computers and improved access to the Internet, email, and other educational resources (Enlaces 2019m). Finally, this year, Enlaces also co-funds broadband access to schools with the aim of improving connectivity (Enlaces 2019m).

In 2006, Enlaces and the United Nations’ Development Programme (UNDP) reviewed a document which dealt with human development and technologies, specially the section dealing with ICTs in education (Enlaces 2019n), the document reiterated that the school had become a focal point to diminish the digital breach for it

was in the school where the students had free access ICTs (Enlaces 2019n).

In 2007, the Government starts implementing the Technologies for Quality Education plan or in Spanish “Plan Tecnologías para una Educación de Calidad” or TEC for short (Enlaces 2019o; Toro 2010). According to Toro (2010), the objective of the plan is to improve the quality of education through the opportunities afforded by ICTs as well as incrementing the existing equipment, and within a period of 3 years (from 2007 to 2010), over 209,000 new computing equipment were delivered (Donoso 2010). The plan was aimed at the preschool, basic, and secondary levels of education (Enlaces 2019o) and was based on three central pillars, namely, infrastructure, teacher’s digital competency, and a new generation of digital educational resources (Toro 2010). The plan had a budget for an investment of US\$200 millions on infrastructure (Enlaces 2019o).

According to Enlaces (2019p) and Donoso (2010) in May 2008, the government implemented a new initiative, and this was known as the “Laboratorios Computacionales Moviles” which was in fact comprised of mobile computer labs and aimed at third year basic education students (Enlaces 2019p). These mobile labs were equipped with a portable computer for the teacher and sufficient similar computers for the students, including Wi-Fi connection (Donoso 2010; Enlaces 2019p). The objective of this initiative was to facilitate a more incorporated approach between teachers and students and technology in which a 1:1 student per computer setting was possible (Donoso 2010; Enlaces 2019p). According to Donoso (2010), the success of this initiative was notorious by the fact that there was a reduction in the number of students per computers, getting it closer to that of developed countries, that is, 1 computer per 9.8 students. Whereas, 4 years earlier, it was possible to have 1 computer per 30 students Donoso (2010).

The year 2009 was a period in which an additionally 21,568 practicing teachers were trained in the use of ICTs and by 2010, a further 20,000 newly graduated teachers were also trained (Donoso (2010). Moreover, during the course of

this year, Enlaces launched the first catalogue of educational digital resources in Latin America (Enlaces 2019q) under the name of “Catálogo de Recursos Educativos Digitales” or referred to as RED for short (de Saint Pierre 2010; Enlaces 2019q). Also, Enlaces (2019q) indicates that during this time, the first national census on educational technology was conducted, and it included municipal schools, subsidized schools, and a small sample of private schools. The collected information related to the infrastructure in the schools, access and use of ICTs by students, teachers, principals, and coordinators (Enlaces 2019q). Finally, Enlaces (2019q) indicates that the result of the census created the Digital Development School Index or in Spanish “Índice de Desarrollo Digital Escolar” (IDDE for short). The index revealed the level of development, the state of the infrastructure, the capabilities of the different human actors, and the management and use of the technology in the schools. During this time, President Michelle Bachelet established a scholarship that was designed to benefit students who were recognized as lacking resources or from a low socioeconomic status and who at the time were enrolled in a public or subsidized school. The scholarship was labelled as the “I Choose my PC” or in Spanish, “Yo Elijo Mi PC” (Toro 2018). As a result, 30,000 PCs were given to those students that met the criteria in the first year of the scholarship and then increased to 60,000 per year (Junta Nacional de Auxilio Escolar y Becas 2017; Colaboradores de Wikipedia 2017). According to figures provided by Junta Nacional de Auxilio Escolar y Becas (2017), since its inception, 350,000 students have benefited as a result of the scholarships and an extra 30,000 who are enrolled in a subsidized school in grade 7 are expected to benefit in 2017. In 2019, the scholarship is continuing, offering students in year 7 of public schools a choice of portable computers, ranging from an Acer Aspire 1 – Intel Pentium 5000 N, HP Stream – Intel Celeron 4100, LENOVO Idea PAD 330 – Intel Pentium 4415 U (Ministerio de Educación 2019b).

In 2010, Enlaces obtained the ISO 9901-2008 quality certification for its Evaluation of Digital Educational Process (Enlaces 2019r). The

scholarship “Yo Elijo Mi PC” continues to benefit students (Toro 2018).

The year 2011 was again another year during which new initiatives were created; more equipment was handed out and evaluations were carried out with the aim on finding out where, what, and how improvements could be made (Enlaces 2019s). It was the first time that the SIMCE test was used to measure the capabilities attained in ICT learning (Enlaces 2019s). The SIMCE which is the abbreviation for “Sistema de Medición de la Calidad de la Educación,” (in English it translates to “Measurement System for the Quality of Education”) and to this day, it is still in operation. The SIMCE is managed and run by the “Agencia de Calidad de la Educación” (in English, “Agency for the Quality of Education”), which was established by Law Article 20.529 and which is tasked to safeguard and monitor the quality of education (Agencia de Calidad de la Educación 2017b; Biblioteca del Congreso Nacional de Chile 2017; Toro 2018). The primary aim of SIMCE is to create a series of tests devised to measure academic performance and the quality of education. These tests are administered to primary students in years 2, 4, 6, and 8, as well as those in secondary education of years 10 and 11. Accordingly, the advocates of SIMCE at the time of its inception argued that these tests would also help parents make informed decisions on the performance of schools and thus enrolling the students at the school of their choosing. It must be clarified that SIMCE was created as part of the market driven reforms that were made to the education system during the Pinochet regime and which viewed education as a marketable commodity (Bellei 2010). Presently, the results are made public and are accessible online with detailed performance results by region, locality (i.e., urban/rural), classification (i.e., private, subsidized, municipal), and by school (Agencia de Calidad de la Educación 2017a; Toro 2018). In addition, though the program “Matemática” which relied on ICTs to teach mathematics also showed that an evaluation of 2906 students in years 5 and 6 of basic education, from 25 separate schools, had demonstrated a significant improvement in maths (Enlaces 2019s).

Also, the year 2011 saw the creation of another free of charge portal where primary and secondary students were able to access content related to the national curriculum (Enlaces 2019s). The available material included videos, simulators, and animated images. In terms of equipment, 417 digital/interactive blackboards were given to a total of 99 schools including pedagogical support to those schools in the implementation and adoption during teaching (Enlaces 2019s). At the same time, 790 schools selected a total of 37,000 educational resources from the RED catalogue to support their work in the classroom (Enlaces 2019s) and 3,000 rural schools received specialist digital resources and training to be used in mixed grades classrooms (Enlaces 2019s).

During 2012, more initiatives were introduced that included the use of ICTs. One of these was known as “Mi Taller Digital” or digital workshop which consisted of extracurricular workshops that aimed to develop the capabilities necessary for the twenty-first century use of ICTs and included such themes as robotics, video games, digital comics, and video editing (Enlaces 2019t). Another initiative was the creation of a platform that included the curriculum content in English, including Mathematics so that students could reinforce their language learning (Enlaces 2019t). Currently, there are over 200,000 students taking part in this initiative (Enlaces 2019d).

The “TIC y Diversidad” (in English, ICT and Diversity) initiative was also developed which included teaching math, science, and history to students with hearing impairment; in fact, by 2014, the totality of schools catering for students with special audio needs were covered by this program (Enlaces 2019u). The coverage comprised the ICT equipment, educational resources, and the training of school personnel (Enlaces 2019u).

The use of tablets as teaching and learning tools by preschoolers was also launched (Enlaces 2019t). The approach for this initiative is set up as stations whereby the students move to and complete a series of exercises and then move to the next station to complete a different set of exercises; these can range from geometric figures, numbers, and logical exercises (Enlaces 2019t).

Finally, the second census takes place to measure the penetration and use of ICTs in schools, the first census had taken place in 2009 (Enlaces 2019t). The results of the census were published in 2013 and permitted the decision-making process around the areas of infrastructure, use, and management ICTs (Enlaces 2019t). Furthermore, the data gathered in previous years by SIMCE TIC indicated that in their ability and use of ICTs, 46.9% of students were at a proficiency level of beginners, 51.3% were at intermediate level, and 1.8 at an advanced level (Enlaces 2019u; Toro 2018). However, the census also concluded in general terms, that only a small percentage of students had met the required level of cognitive abilities necessary for the processing and generation of information (Enlaces 2019u).

In 2015, President Michelle Bachelet announced the creation of a new program by the name of “Me Conecto Para Aprender” or in English, “I Connect to Learn” (Enlaces 2019v). The program meant that all year 7 students enrolled in public education would receive a laptop and its main objectives were to further reduce the gap in access and use of ICTs, to improve the quality of education, and to support the learning of those student enrolled in a public school (Enlaces 2019v). In addition, part of this program also included pedagogical material related to the use of ICTs and was aimed at the teachers as well as the student’s family (Enlaces 2019v). As a result, Enlaces (2019v) indicates that 70,000 students benefited under this scholarship. Also, according to figures provided by Junta Nacional de Auxilio Escolar y Becas (2017), since its inception, 350,000 students have benefited as a result of the scholarships and an extra 30,000 students benefited in 2017 (Ministerio de Educación 2017), and by 2019, about 130,000 students would be able to receive a computer (Ministerio de Educación 2019a, b). However, the year 2015 also saw the creation of a pilot program which was a first for Enlaces which together with the Special Education unit (Enlaces 2019v), launched the program labelled “TIC y Retos Múltiples” (in English it would translate to “ICTs and Multiple Challenges”), and consisted in trying to define a pedagogical strategy and a set of assistive

technologies that would promote via the use of ICTs, access to communication and involvement, the development of autonomy and knowledge on students who presented multiple disabilities (Enlaces 2019v).

The following years, 2016–2018 saw the expansion of Wi-Fi connectivity, more reconditioned computers were handed out to replace obsolete models found in some schools (Enlaces 2019e), and by 2018, 40% of students attended a school with optic fiber connectivity (Enlaces 2019a). Also, continuing from workshops conducted in 2018 is the National Plan of Digital Languages 2019 which seeks to develop digital capabilities, creativity, logical thinking while learning a programming language (Enlaces 2019d).

A Measure of Success

In almost 30 years of existence, Enlaces through its many initiatives has undoubtedly been a success in terms of practically reaching universal coverage, that is, students in basic and secondary schools owning or being able to have access to ICTs in schools (Donoso 2010; Enlaces 2019p). Moreover, Enlaces has been able to diminish the digital divide that impacted disadvantaged students and to change negative perceptions by some teachers and principals on importance of ICTs in education (Hinostroza and Labbé 2010). However, there is still some work to be done towards the expansion into preschool years where access to ICTs is yet to be universal (Donoso 2010). The benefits from Enlaces have not just been experienced by the students, but teachers have also been able to access, learn, and incorporate ICTs as part of the daily teaching activities (Donoso 2010). As argued by Oteiza and Miranda (2010), Enlaces has brought about a consensus across the political spectrum on the necessity to expand the access to ICTs. In addition, Oteiza and Miranda (2010) indicate that changes in education tend to be slow and less visible in the short term and so initiatives need to be maintained for prolonged periods of time. However, the process of introducing ICTs is a

complex one and is not limited to the delivery and plugging in of some ICT equipment (Oteiza and Miranda 2010). In fact, the introduction of ICTs can be seen as a cultural change that impacts and permeates the many aspects of society such as the social, cultural, and economics dimension (Hinostroza and Labbé 2010; Oteiza and Miranda 2010; Toro 2018).

Even when from an implementation and coverage perspective, it can be argued that Enlaces has been a success (Bellei 2010), this argument can be deduced from a singular perspective whereas, while these reforms and initiatives were being implemented, the country experienced a number of protests carried out by students calling for a more equitable and affordable education as the current system still contains the vestiges of the market driven reforms from the Pinochet years (Bellei 2010; Toro 2010, 2018). Chile remains one of the most unequal of the OECD countries and performance results seem to have reached a plateau (OECD 2016, 2017a, b, 2019). However, this is no reason to scale back or terminate the Enlaces initiatives. In fact, it remains to be seen if other social initiatives coupled with further but more inclusive education reforms can bring more universal benefits in the longer term.

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Information and Communication Technologies' Pedagogical Affordances in Education

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Synonyms

Digital technology in education; ICT in education; ICT integration; ICT pedagogical affordances

Introduction

Information and Communication Technologies (ICTs) have encroached in education systems to a degree that they have become an integral part of the educational ecosystem. Though the integration of ICT in education has been a contentious issue, there is no way to ignore it because of the pedagogical benefits in the classroom. The growing presence of various ICT applications in schools impacts teaching and learning as ICT is now fundamental in the knowledge economy and the educational ecosystem. This has resulted in new ways of learning and teaching in a complex digital environment (Bartlett-Bragg 2017). Digital technologies are widely seen as enhancing teaching and learning, thus fuelling their rapid adoption and integration in the classroom. Their rapid growth in education has resulted in the pursuit of alternative pedagogical approaches throughout developed and developing societies. ICT integration in education holds great appeal to learners as it has the potential to transform and disrupt traditional teaching practices (Blin and Munro 2008). The Oxford English Dictionary defines disrupt as “(1) disturb or interrupt and (2) seriously alter or destroy

the structure of.”¹ This work was based on the thematic analysis of many studies, including coding and categorization, which resulted in eight technology affordances constructs: responsiveness, equity, processing data, social connecting, podcasting, virtual connecting, multimodal, and integrated writing.

The presence of ICT in education has ushered in unparalleled transformation in knowledge representation and pedagogical practices and introduced new methods of communication, presentation of information, and presentation of text, unlike before where information was presented in a linear and single-media format (Díaz Andrade et al. 2017; Thapa and Hatakka 2017). According to Dlamini and Mbatha (2018) the “prevalence and adoption of Information and Communication Technology tools in education has often been guided by utopian perspectives without proper research to understand the schooling context and teachers' ICT development needs” (p. 17). This exploratory work was conducted within the constructivist perspective in an effort to contribute to the ongoing debate over whether ICT should be conceived as supporting tools or as an integral part of cognitive development.

The scope of the systematic analysis was limited to studies published between 2007 and 2017, and the focus was defined by four thematic classes specified in the Human-Computer-Human Interaction (HCHI) model (DiGiuseppe and Partosoedarso 2014) adapted from Desjardins and Bullock (2012): technical interactions, social interactions, informational interactions, and computational interactions. In each class we sought to uncover multiple perspectives and interpret them in relation to affordances and multimodality. To complement the Human-Computer-Human Interaction (HCHI) model, we engaged three generations of distance education pedagogy (Anderson and Dron 2011) to gain insights into the dimensions of ICT pedagogical affordances which signals change in the education landscape. The increase in educational technologies signals the

¹Dictionary, O. E. (2003). Oxford English Dictionary.

need for a generic framework for learning technologies. In South Africa, for instance, the government is investing heavily on computing infrastructure in schools, but the uptake is very slow and still “still grappling with issues of professional teacher development in ICT” (Dlamini and Mbatha 2018, p. 18). According to UNESCO (2003, p. 118), spending scarce resources on ICT without financing teacher development is wasteful. Beyond ICT infrastructure, educators and learners are expected to create learning objects and communicate ideas to solve problems and work collaboratively.

The pace of technology development is unbelievably fast; therefore, we must not be alarmed and instead try to keep up with the pace. Education needs should drive technology adoption and create new value in a technology-enabled education ecosystem. The potential for ICT in education is enormous as it promotes inclusion and demands an innovative approach to teaching and learning. Hartley (2007) asserted that the intersection of the teacher and education expands the horizon of the learner and the communication channels contribute to another unobtrusive social change. Building on the inclusive discourse, mobile technologies increase knowledge and information access in all sectors of the economy, and education is no exception (Aker and Mbiti 2010; Donner and Tellez 2008). Yang et al. (2011) confirm that mobile technology “provide individuals with unprecedented connectivity to information and inter-personal interaction” (p. 1). This work argues that ICT affordances contribute to teaching and learning and enhance social capital. The ICT affordances are aligned with the relational property of a three-way interaction posited by Anderson (2003a). The three-way interaction consists of students, content, and academic staff to enable greater engagement and ultimately create personalized learning experiences.

The aim of this study is to present a conceptual argument about ICT or technology affordances in the process of articulating what is known and what still needs to be understood about ICT integration in education. This entry addresses two questions relating to ICT pedagogical affordances in education:

1. What are the pedagogical ICT affordances in the process of learning?
2. What are the implications for ICT integration in education?

This work contributes to the new sustainable development goal on education for 2030 which has been set to “ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.”² In developed economies, research has demonstrated some key drivers and mechanisms for improving standards in schools by making effective use of technology (National Research Council 2011; Roehrig et al. 2007; Hardman et al. 2008). Instead of teachers using ICT to change the learning experience, they replicated their passive practices with technology and thus were not able to reap the benefits of ICT affordances. Given the poor preparedness of teachers to handle the influx of ICT tools, we can easily conclude that teachers are not fit for the new demand of the twenty-first-century classroom. Yet, it could be that they have been sidelined with no ICT development opportunities mapping ICT affordances to teaching and learning.

An affordance perspective represents a relational approach to understanding how people interact with technology (Leonardi 2013). Affordances advocate focusing on relational actions that occur among people and technologies (Faraj and Azad 2013). The best example is the increased use of digital technologies as a ubiquitous productive tool and as an integral part of cognitive development. As such, our aim is to learn what other scholars and research groups have been doing with ICT in education. This is an effort to advance the discourse in the integration of ICT in teaching and learning and to disguise deep animosity to technology by teachers. Our goal is to demonstrate how putting technology in a more subservient role to that of pedagogy is misplaced. The intersection of technology and pedagogy has the potential to “reveal and develop our human creativity and responsiveness and

²<http://www.un.org/sustainabledevelopment/education/>

allow us to learn effectively and enjoyably” (Anderson and Dron 2012, p. 2). Despite the loadable benefits of inclusivity, our work explores further ICT affordances in order to make them visible to all educators and explain how they add value to learning and how they widen the context of learning. Digital technologies' ubiquitous characteristics must be more visible in order to understand how they promote active learning and enhance the classroom experience.

Education Intersecting with Digital Technology

Melton and Kendall (2012) asserted that smartphones, tablets which enable ubiquitous computing, video conferencing, and social networking are now deemed necessary tools in education. These tools have become the place where people intersect with technology; however there is a need for guided pathways to interact with information. According to Condie and Munro (2007, p.4), ICT “can support creativity, including critical thinking skills and problem solving abilities” particularly those with strong visual elements and related resources [multimedia presentation]. While critics have doubted the role of ICT in education, it is difficult to dispute learners' experience and enthusiasm to networked digital literacies. Digital literacies are inclusive of information literacy, computer literacy, network literacy, and media literacy (Bartlett-Bragg 2017, p. 16). Thus, digital fluency has become the basic skill necessary to address huge amounts of information available in digital platforms.

Though there is little evidence of disruption, the study focuses on the ICT affordances to alter the structural impediments to transformation of teaching and learning. Currently, the use of ICT in education is “sporadic, uneven, and often ‘low level’” (Selwyn 2007, p. 84). Instead of giving in to the “demands of the global economy and blindly following the unforgiving logic of contemporary flexible capitalism” (Selwyn 2007, p. 89), it is important to have a comprehensive understanding of the ICT affordances. According to Laurillard (2007, p. XV):

[...] we tend to use technology to support traditional modes of teaching – improving the quality of lecture presentations using interactive whiteboards, making lecture notes readable in PowerPoint and available online, extending the library by providing access to digital resources and libraries, recreating face-to-face tutorial discussions asynchronously online – all of them good, incremental improvements in quality and flexibility, but nowhere near being transformational.

Therefore, to experience transformation, educators must be able to map the ICT affordances to the principles of learning to democratize and enhance access to epistemology through interactivity and collaboration (Woolard 2012). The White Paper on e-Education (2004) asserted that ICT offers greater opportunities to widen access to learning, redresses inequalities, and improves the quality of teaching and learning in schools. In an effort to promote structural transformation in the classroom, there is a need to adopt new digital pedagogical approaches [transference of existing pedagogies]. ICT disrupts teaching practices in the classroom; therefore, there is demand for transformative ways to improve the current passive and content driven models of the classroom. According to Redmond (2011, p.1050), “ICTs offer new opportunities....” The disruptive nature of digital technologies must be embraced by educators “who in the past had not been able to do [something] themselves for lack of money or skills” and who “welcome a simple product,” which will enable them to “do more easily and effectively what they are already trying to do” (Christensen et al. 2002, p. 475). The diffusion of technologies in the classroom demands new approaches to teaching and learning in order to accommodate the diversity of learners.

The major challenge is the integration of ICT in the classroom in order to realize the potential of emerging technologies to make classrooms dynamic spaces of learning and development. According to Carlson and Gadio (2002), “Experience around the world in developing, industrialized, and information-based countries has shown that teacher training in the use and application of technology is the key determining factor for improved student performance (in terms of both knowledge acquisition and skills development

enabled by technology)" (p. 119). Despite the many benefits, ICT integration demands a systematic approach; when meaningful appropriation is realized, the resulting enrichments can be manifold.

This research entails extensive searches of relevant literature published in various education journals and proceedings from relevant conferences on ICT in education and ICT-enabled schools. The journal articles explicitly explain how ICT supports education and transform the classroom. In our search we were mindful of the quality and credibility of the articles to ensure trustworthiness, confirmability, dependability, transferability, and credibility (Lincoln and Guba 1985). In order to establish confidence in our presentation, articles from different parts of the world were engaged both from developed and developing economies to maximize the validity and reliability of the study. To further strengthen this work, we studied the authors to ensure that their credentials are impeccable, over and above the fact that the articles appeared in credible journals. According to Patton (2002), the information rich data yields "insights and in-depth understanding rather than empirical generalizations" (p. 230). In order to make credible claims, we performed an in-depth analysis to ensure information rich analysis (Patton 2002, p.40). This was to substantiate any claims made in the study. The strength of the approach was that the articles reviewed provided multiple perspectives on ICT applications in schools and how they impacted teaching and learning. The journal articles were written by credible researchers who are experts in the educational technology field and came from different parts of the world. The inclusiveness of the literature dissuades any credibility questions that may arise.

Conceptualizing Affordances

Digital technologies have become a highly valuable resource in education and are deemed necessary tools in education (DiGiuseppe and Partosoedarso 2014; Melton and Kendall 2012). Without a doubt learners in schools are exposed to

a variety of digital devices and applications. Therefore, it is important to have a deeper understanding of technology affordances and how they contribute to teaching and learning. The term affordance was first coined by Gibson, and then McGrenere and Ho (2000) expanded Gibson's definition to cover both usability and usefulness. In our case, affordances are considered in relation to human computer interfacing (HCI) as applicable in education and in connection with the opportunities that technologies bring into teaching and learning (Hammond and Manfra 2009; Hammond 2011). While ICT tools are perceived as useful education tools that support learning activities, we want to unearth the features of technology that support pedagogical activities.

The affordance perspective was popularized in design and human-computer interaction research by Norman (1988), who defined affordances as the design aspect of an object. This definition argues that the nature of an object informs how it should be used. However, subsequent scholars argued that affordances can emerge through direct interaction with technologies, which often leads to processes of experimentation and adaptation that shape the actions people take with technologies (Leonardi 2011; Evans, Pearce, Vitak & Treem 2016). Gibson's theory of affordances proposes that "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (Thapa and Hatakka 2017). The potential value of technology affordances in education is most relevant in the large classrooms and contemporary teaching and learning environments.

Many researchers cited Gibson's definition of *affordances*, yet there was little consistency in the application of the term among these papers, and hence there is no agreement on a conceptual definition of affordances (Parchoma 2014). From the users' perspective, the relational ontology suggests that affordances emerge in practice in a particular context (Canole and Dyke 2016). In this work, we present a detailed account of ICT in education and how ICT affordances enable educators and learners to achieve cognitive development. To help bring a systematic approach, we will present an account of how technology

enhances education in general and then move on to the specifics through Vygotskian's perspective of teaching and learning. We look at the interaction between educators and content, learners and content, as well as educators and learners (Anderson 2003a). In Anderson (2003a) the three-way interaction consists of students, content, and academic staff. Furthermore, we argue against the notion that affordances exist independent of the user.

Mapping ICT Affordances to Four Principles of Learning

Governments invest a lot of money on ICT initiatives; however the uptake is disappointing given the well-documented ICT affordances to create learner-centered environments. Therefore, the provisioning of ICT infrastructure must not be construed as automatically affording learners attainment because there is intrinsically nothing in the provisioning of ICT tools that automatically guarantees cognitive development. There is a disappointing slow uptake of ICT in education even though high investments have been made to improve ICT access. There is a gap between schools' access to ICT and teachers' readiness to pedagogically integrate ICT tools into teaching. It should be noted that the demands of transformation of the classroom are real and beyond the rhetoric and the hype around emerging digital technologies.

The First Principle of Learning: Autonomy

ICT has the potential to promote and encourage ubiquitous learning which supports the learner-centered approach. ICT's transformative nature stresses the use of ICT as a lever for instructional change (Vanderlinde and van Braak 2010). Christensen et al. (2008) argues that, "the data suggest that by 2019, about 50 percent of high school courses will be delivered online." With this in mind, educators must prepare to meet this challenge with an open mind and look to disruptions

that may be taking place in the present for guidance in preparing for the future. The twenty-first century challenges many educators to rethink what they teach and how they teach (McLoughlin and Lee 2008). Given the affordances of ICT resources and their influence on teaching and learning, it is important to adopt technology-driven pedagogy that supports interactivity and learner-centered classroom environment.

The Second Principle of Learning: Connectedness

The best approach that supports digital pedagogy seems to be connectivism is known to be aligned with the digital age and network society. There is a strong belief that through simulations and gamification high-order thinking skills are developed (Clarke and Clarke 2009). However, digital fluency is key to realizing the full potential of ICT affordances especially continuous interaction with subject content, concepts and terminologies. Wang et al. (2012) define digital fluency as the ability to reformulate knowledge to express oneself creatively and appropriately using digital technologies. Furthermore, Lai (2011) asserted that the potential benefits of digital technologies depends on its capacity to support interactivity.

The Third Principle of Learning: Diversity

Digital technology expands access, collaboration, and affordability to education. South Africa is confronted with an unprecedented unequal access to quality education, particularly in rural communities or under-resourced communities; there are crucial issues that have not been adequately addressed such as teachers' preparedness to teach in the contemporary and diverse classrooms. These technologies have the potential to enrich interactions and enhance engagement with content (Canole and Dyke 2016). Digital platforms provide environments to share content and present content in multiple forms (Canole et al. 2016). However, research shows that the "pedagogical

and technical expertise of the teacher is absolutely critical” for the integration of ICT into teaching and learning (Hennessy, Harrison and Wamakote, 2010, p. 40). The potential for digital technologies to transform teaching and learning is great as long as they are used as a pedagogical tool to present content in multiple formats.

The Fourth Principle of Learning: Openness

Klopfer and Squire (2008) says that technology can have a reciprocal relationship with teaching. The emergence of new technologies pushes educators to understand and leverage these technologies for classroom use; at the same time, the on-the-ground implementation of these technologies in the classroom will directly impact how these technologies continue to take shape. Undoubtedly, without these technologies such as digital games and digital interactive activities in the classroom, strong lessons can still be achieved, but there is a sharp disconnect between the way students are taught in school and the way the outside world approaches socialization, meaning-making, and accomplishment.

Dimensionality of ICT Affordances in Education

Consistent with ICT affordances' attributes in producing various forms of social interaction and changing ways that learners engage with content and educators engage with learners, we present the dimensions of ICT affordances. These dimensions are presented through the Human-Computer-Human Interaction (HCHI) model [technical interactions, social interactions, informational interactions, and computational interactions] lens, complemented by the three-way interaction posited by Anderson (2003a) consisting of learners, content, and educators. In order to present meaningful understanding, we propose three questions: (1) What are the essential characteristics of ICT that can transform instruction delivery in the classroom? (2) In what ways are digital technologies enabling teachers and

learners to bridge knowledge gap? (3) How does ICT contribute toward the development of twenty-first-century skills [conceptualizing, abstraction, generalization, problem-solving, and information processing (Cassim 2010, p. 1)]? To explicate the concept of ICT affordances and make them useful in education, we present various interactions supported by digital technologies. In this section we are interested in capturing how ICT affordances support the principles of learning: autonomy, connectedness, diversity, and openness.

We consider ICT affordances as process concepts; thus this work is an effort to operationalize and bring meaningful linkage between pedagogical choices and technology affordances. There is value in having deeper understanding of digital technologies categories and the link to digital technologies affordances in order to develop a systematic approach to integration in education. This has the potential to enable educators to adopt and use technology in teaching and encourage a different perception toward digital technologies. According to McGrenere and Ho (2000), affordances have three fundamental properties (p. 1):

- An affordance exists relative to the action capabilities of a particular actor.
- The existence of an affordance is independent of the actor's ability to perceive it.
- An affordance does not change as the needs and goals of the actor change.

In each class we sought to uncover multiple perspectives and interpret them in relation to affordances and multimodality. To complement the Human-Computer-Human Interaction (HCHI) model, we engaged three generations of distance education pedagogy (Anderson and Dron 2011) to gain insights into the dimensions of ICT pedagogical affordances which signals change to the education landscape. Table 1 demonstrates how ICT affordances support the Human-Computer-Human Interaction (HCHI) model and contribute to clarifying the confusion surrounding technological affordances in education. The key is to manage both conceptual and technical

Information and Communication Technologies' Pedagogical Affordances in Education, Table 1 Linking digital technologies categories with digital technologies affordances

Human-Computer-Human Interaction (HCHI) model (Desjardins 2005)	HCHI model description. (DiGiuseppe and Partosoedarso 2014) Adapted from (Desjardins and Bullock 2012)	Digital technologies categories	Digital technologies affordances	References
Technical interaction (TI)	Employ basic devices and applications; create/edit documents/multimedia (p. 340)	Hardware technologies Mobile devices	Interaction between humans and machines Editing documents Principles of learning: autonomy, connectedness, diversity, and openness	(Asoodar et al. 2016; Bamanger and Alhassan 2015; Isaacs 2012; Yang et al. 2011; Zevenbergen and Lerman 2008)
Social interaction (SI)	Communicate via email, video, text, audio; use social networking systems (p. 340)	Discourse facilitation Virtual environments Virtual realities Video Texting Audio Social media Web-based Content management systems	Multiple representation Active participation Sharing of Information and Ideas Social networks Collaboration eLearning Multimodal interaction ePresence Visualization Collaborative game problem-solving Interactive learning environment Principles of learning: autonomy, connectedness, diversity, and openness	(August et al. 2016; Squire 2008, 2011; Campbell and Martin 2010; Fetaji et al. 2007; Slay et al. 2008; Zevenbergen and Lerman 2008)
Informational interaction (II)	Search for and exchange articles, video, music, books, etc. (p. 340)	Learning management system Smart glasses Databases Content management systems	Sharing of information and ideas Multimodal interaction Searching for articles Principles of learning: autonomy, connectedness, diversity, and openness	(Canole and Dyke 2016; Campbell and Martin 2010; Slay et al. 2008)
Computational interaction (CI)	Create concept maps, plans, diagrams, pictorials, graphics; process data (p. 340)	Learning management system Content management systems	Connectivity Multimodal interaction Learning analytics Complex calculations Principles of learning: autonomy, connectedness, diversity, and openness	(Campbell and Martin 2010; Digregorio and Sobel-Lojeski 2010; Slay et al. 2008; Zevenbergen and Lerman 2008)

characteristics in order to design, develop, and implement innovative ways in the classroom to realize distributed understandings. These technologies provide innovative ways to move learners

from a passive approach to higher levels of conception and analytical capabilities (Dabbagh et al. 2015; Josephson 2013). Educators' ability to integrate technology in the classroom affords them

the opportunity to pursue alternate pedagogical approaches through various interactions.

These alternative pedagogies are informed by ICT affordances enriched by Vygotsky's approaches to learning at social and individual level. Further, they extend access to learning through a vast range of diverse experiences. "ICT allows us to create, collect, store and use knowledge and information; it enables us to connect with people and resources all over the world, to collaborate in the creation of knowledge and to distribute and benefit from knowledge products" (Tondeur et al. 2011, p.152). In Table 1 there is clear evidence that ICT affordances give teaching and learning new discoveries whereby text can be presented in a variety of formats such as audio, video, and animations and support both synchronous and asynchronous communication. The ubiquitous properties in digital technologies allow learning without boundaries, continuous experimentation, and active experiential learning. ICT has a significant role to play in information sharing, social mobilization, visual representation, education, digital footprints, and instructional delivery (Dlamini 2015). According to Kuriya et al. (draft), ICT "provides multi-platform opportunities for dissemination and interaction with information" (p. 6). The effectiveness of technology affordances can be summed up according to the following constructs to ensure that they serve their purpose and add value in education:

- **Responsiveness** [increased interaction – Educator-Content, Learner-Content, and Educator-Learner]
- **Equity** [equitable access to information, real-time interaction, and flow of information]
- **Processing Data** [data analytics for intelligent insight and spatial issues affecting cognitive activities]
- **Social Connecting** [allow continuous peer-to-peer connection to interact beyond the physical classrooms and continuous flow of information]
- **Podcasting** [digital audio recording to increase interaction with content knowledge]
- **Virtual Connecting** [virtual experimentation to develop deeper understanding of concepts]
- **Multimodal** [multiple representation of text, knowledge, learning objects, etc.]
- **Integrated Writing** [used of multimedia applications and screen-based technology to support word processing and discover useful information to enhance writing]

Table 2 indicates the technology affordances constructs being supported by the literature as we continue to develop deeper understanding of the role of technology in education. The use of technology in schools remains uneven across classrooms. This could be attributed to ICT competency level of educators in a school and also the priorities of the political vision. In this article we have unearth and organize some of the technology affordances with potential to revolutionize the classroom. Asoodar et al. (2016) stated that "podcasting can be a complement to the class material" (p. 876). An analysis of findings conducted to a group of 200 first-level students confirmed that students prefer podcasts than their textbooks and notes (Asoodar et al. 2016; Evans 2008). The rapid growth of mobile devices could be significant in this discourse as they allow individuals to access content continuous, anywhere and anytime.

Bamanger and Alhassan (2015) averred that "mobile digital technology devices such as MP3 players, iPods, iPads, and smart mobile phones could offer their users the opportunity to access information almost anywhere, at any preferred time and at their own pace" (p. 63). With such advancement in digital devices and technologies, the limitations of the classroom are eliminated. The demand of the contemporary learners is "convenient learning"; therefore the ubiquity of technology provides learners with that flexibility and allows them to engage with materials beyond the face-to-face lectures. Given that podcasts for an example are in audio format enhance acquisition of knowledge and literacy development (McKinney et al. 2009; Kurtz et al. 2007). Today, we witness the unprecedented growth of interactive whiteboards (IWBs) in the classrooms, which is considered one of the most revolutionary instructional technologies that facilitate learning in different ways (Türel and Johnson 2012; Campbell

Information and Communication Technologies' Pedagogical Affordances in Education, Table 2 Literature supporting technology affordances constructs

	Responsiveness	Equity	Processing data	Social connecting	Podcasting	Virtual connecting	Multimodal	Integrated writing
Canole and Dyke (2016)	X	x	x	X		x	x	
Dabbagh et al. (2015)	X	x	x	X		x	x	
Josephson (2013)	X	x	x	X		x	x	
Anderson and Dron (2011)	X	x		X		x	x	
Dlamini (2015)	X	x					X	
Kuriya et al. (draft)	X	x		X		x	x	
Tondeur et al. (2011)	X	x		X		x	x	
August et al. (2016)	X	x	x	X		x	x	
Fetaji et al. (2007)	X	x	x	X		x	x	
Bhalla (2013)	X	x	x				x	
Vanderlinde and van Braak (2010)	X	x					x	
Dede (2013)	X	x	x	X		x	X	
Atai and Chahkandi (2012)	X	x		X		x		
Asoodar et al. (2016)	X	x		X	x		x	x
Bamanger and Alhassan (2015)	X	x		X	x		x	X
Squire (2011)		x		X			x	
Campbell and Martin (2010)	X	x		X		x	x	
Pinto-Lorente et al. (2017)	X	x		X		x	x	x
MacArthur (2009)	X						x	x

and Martin 2010; Digregorio and Sobel-Lojeski 2010).

Türel and Johnson (2012) confirmed that IWBs enhance the functionality of existing technologies by adding interactivity and “increase students’ attention, motivation, participation, and collaboration” (p. 381). The functionality of IWBs have positive effect on learning as content is represented in multiple ways and various media can be used to accommodate different learning styles and enhance social interactions. The ability to record interactions, capturing of screenshots, and use of visual media is a plus (Türel 2010, 2011; Slay et al. 2008). These functionalities have pedagogical implications for educators to transform their pedagogy into more student-centered and interactive learning. Despite the diversity of the studies, notably the majority of the research presented in Table 2 supports the technology affordances constructs. There is also alignment with various interactions in the Human-Computer-Human Interaction (HCHI) model (Desjardins 2004) and the three-way interaction posited by Anderson (2003a).

Discussion and Future Issues

We engaged with digital technologies categories and linked them with technology affordances to develop deeper understanding of how they afford unique opportunities to learning. These technological affordances were conceptualized around their diverse potential relationship with education. We then present six constructs of ICT affordances with conceptual descriptions to allow scholars in the field to further conduct empirical research on this constructs. These constructs have practical implications for the teaching profession and practice. We hope this entry will encourage further empirical studies on ICT affordances in education to gain deeper understanding and improve adoption and appropriation in the classroom. In the literature there is no doubt about the role of ICT in education and is clear that there is a belief that it can enhance learning (Livingstone 2012). According to Livingstone (2012), ICTs “bridge forms of knowledge and literacy, and they

intersect places of learning—home, school, work and community” (p. 10). DiGiuseppe and Partosoedarso (2014) confirm that computer-based applications and digital devices enable ubiquitous learning.

The use of computer-oriented communication has the potential in collaborative learning especially through the use digital technologies such as videos, animations, images, etc. However in order to experience such affordance, there must be meaningful interactions between learning environments and learning objects. These technologies can also be used beyond the learning environments especially in teaching practice whereby digital platforms can be developed and used to share knowledge and teaching materials. This will also allow pre-service teachers to share their experiences and reflect on their teaching within a supportive teaching and learning community. Boud et al. (1993) defines learning as a holistic activity that needs to connect with people’s life experiences. The fact that digital technologies are ubiquitous in nature guarantees that individuals can access information and learning resources beyond the physical book and in the process connect, share, and collaborate in virtual environments. According to Pegrum (2014), mobile devices “represent a return to embodiment, augmenting our brains and our senses as we interact with the world around us” (p. 3). Therefore, the possibilities of ICT in education are enormous given their ubiquitous property and the transformation of space and time.

The adoption and appropriation of digital technologies in schools could push the frontiers of innovation as educators collaborate and share knowledge in virtual spaces. We are mindful of affordability especially in our context, though mobile technology has been described as the technology of choice in Africa (Pegrum 2014). Accessing equal and quality education has been a challenge in developing nations; thus the potential of digital technology to expand access to education is great. Table 2 provides a clear picture of how digital technologies can enable teaching and learning. For example, South Africa is confronted with unprecedented unequal access to quality education, especially in rural and under-

resourced communities. There are crucial issues that have not been adequately addressed such as teachers' preparedness to teach in the contemporary classroom and massive youth unemployment. Therefore in order to create opportunities to alleviate such problems, there must be investment in digital education platforms to help the country reconfigure professional and cognitive development initiatives to address the endemic challenges.

ICT affordances unlock the education space allowing the development of virtual communities and multi-representation of learning objects. Thus educators and learners access a broad array of education enrichment activities to complement their regular school curricular activities. Teachers will also have the opportunity to continuously develop their subject knowledge via the virtual community learning centers. This is to ensure that teachers have content knowledge at the appropriate level to eradicate underperformance which is attributed to the socioeconomic status of communities they serve. Digital learning platforms integrated with smart technologies has the ability to monitor learners' knowledge development in real time and provide continuous feedback on their knowledge level. This is particularly true for schools, where efforts are being made to bridge formal and informal learning.

According to Jagušt et al. (2018), "70–80% of learning takes place outside of the formal learning environment and happens spontaneously and unintentionally, in the so called informal context." Virtual and social networks have a role to play given that the out-of-class learning is the dominant way of knowledge building. However, scoping this conceptual presentation of affordances and linking them with cognitive development through empirical work remain. The evidence to support the eloquent claims being made is crucial as politicians and governments grapple with the claim that ICT enhances teaching and learning. Empirical work in this area will have a profound impact on ICT adoption and appropriation in an effort to transform pedagogy to meet the demands of the twenty-first-century classroom. This can result in Just-In-Time solutions to the disruptive nature of digital devices in the classroom and the

effort to construct social constructivist environment.

Implications and Conclusion

The intention of this work was to present technology affordance and their potential value in education. In Tables 1 and 2, we presented snapshots of how ICT affordances suit a diverse range of learners that coexists in a classroom. We organized the ICT pedagogical affordances according to four key principles for learning, autonomy, connectedness, diversity, and openness, and further present technology affordances construct based on our reviewing of the literature. It is evident that technology has the potential to transform pedagogy of personalization giving students the choice of what, when, and how they engage with education resources for cognitive development. Although the majority of the research presented in Table 2 supports the technology affordances constructs, there are different points of view. These points of view provide a more nuanced picture of the research activities and can help further inform the design of future empirical studies. At the same time, it became clear that empirical work to support the eloquent claims being made in the literature needs to be part of the research activities in education. The empirical work investigated the effects of various Technology Affordances Constructs to gain additional insights on how they impact learning and emotional engagement with text. In addition, we performed an analysis of the unique perspectives on digital technologies and how they support cognitive development at various levels of ability and competencies.

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Information and Communication Technology (ICT) in Education

► Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses

Information and Communications Technology

► Computers and Educational Improvement

Information Communication Technologies

► Different Methodological Approaches to Considering the Adoption of ICT

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► IT on Teaching and Learning Process of Visually Impaired Students

► Modeling the Process of Information Technology Innovation in Education

Information Technology and Assessment

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Synonyms

Computer-assisted assessment; Dependability in e-assessment; E-assessment; Educational assessment; Feedback; Formative assessment; Information and communication technology (ICT); Interactive whiteboard; Internet-based assessment; Learning environment; Online quizzes; Security in e-assessment; Students' performance; Summative assessment

Introduction

Technology plays an important role in teaching, learning, and assessment in schools and higher education institutions. The use of computers in assessing learning is becoming widespread in

educational institutions. Assessment and learning are viewed as integral to each other; therefore, computer-based assessment – assessment using information and communication technologies (ICT) – or e-assessment is a tool that is sought to help in bringing about pedagogical change and improve teaching and learning (OECD 2010). The use of online technology in assessment has increased in recent years. This included the entire assessment process, from designing assignments, such as online assignments, quizzes, homework, and examinations, to storing the results with the help of ICT (Fluck et al. 2009). Computer-based interactive simulations have also been reported to be used in assessing students' performance (Neumann et al. 2010). Computer-assisted formative and summative assessment is being used in higher education institutes for assessing students in various subjects, especially for those with learning difficulties and special needs (Perkin et al. 2007). E-assessment is expected to enhance the implementation of e-learning and help in making it considered as much more than a textbook on screen (Weippl 2007). It is sought to provide solutions to some of the challenges for e-learning, in particular through the support of learners through formative assessment and detailed feedback. Assessing various cognitive levels using ICT, as well as improving problem-solving and higher-order thinking skills, was reported by Nirmalakhandan (2007).

E-assessment Types and Tools

Many types of e-assessment tools and tasks have been reported in the literature (Stodberg 2012) such as closed questions (multiple-choice questions (MCQs), matching, and true and false), open-ended questions (short answer and essay type), portfolios, product designs (computer programs, prototypes, and artifacts), and discussion blogs. Various IT assessment tools can be used in the classroom, including computer-based tests (Barncord and Wanlass 1999), interactive whiteboards (Firmin and Genesi 2012), and other various tools. E-assessment can be applied for both formative, where feedback on answers

is given to students to support their learning, and summative assessment, where a grade representing students' achievement is given as a final judgment (Naude et al. 2010). Closed questions format is the most used type of e-assessment, as its grading is reliable and secure. Digital portfolios are tools to measure higher-order thinking and social skills. They help students develop organizational abilities, showcase their talents and creative skills, follow up their progress over time, and advertise themselves. Online portfolios allow students to store their artifacts and media products, and it can be presented to a larger number of audience. E-assessment may also include pre- and posttests, diagnostic tests, and authentic or project-based learning.

Interactive whiteboards play an important role in enhancing teaching and implementation of ICT in the classrooms. It allows teachers to cover the three modes of learning: visual, auditory, and tactile (Landis 2005). Being able to save the lessons using interactive whiteboards and move your notes into other softwares allows teachers to create lessons at home and students to review their lessons anywhere after the class. It also helps special needs students, promotes interaction among students as well as between teachers and their students, and improves motivation of students (Landis 2005). Another newer form of interactive whiteboards are the portable wireless tablets, which operate in a similar way. It also allows teachers to control what is displayed on the board from a distance.

Weblogs, podcasts, and wikis are entering the classrooms, and they could facilitate assessment. They involve thought reflection, resource sharing, and peer interaction (Chen and Bonk 2008). Weblogs are websites with dated posts and comments on other visitors' posts. They offer a record of students' progress. It allows students to explore a topic in more depth and build on one another.

Formative and Summative E-assessment

Technologies of e-assessment are not seen as in themselves being inherently either formative or

summative, but rather the way we use the assessment tool determines whether it is either (Ashton et al. 2004). Formative e-assessment is an easy way of introducing technology in the assessment process in higher education institutions. Pachler et al. (2010) defined formative e-assessment as the use of ICT to support the process of gathering and analyzing students' learning and attainment of the course intended outcomes by teachers.

According to Ashton et al. (2004), computers have a role in at least four forms of assessment: diagnostic testing, self-testing, continuous assessment, and summative assessment. The first three forms are considered formative assessments. Computer-based assessment is particularly effective in formative assessment, as it provides immediate feedback, which is essential to formative assessment. Objective testing (multiple-choice questions) is normally associated with e-assessment. Other types of questions have been included in computer-based testing; however open-ended questions requiring a free text response are often absent from e-testing due to limitations in computerized assessment technology (Vardi 2012). These difficulties may be overcome as the technology improves. The integration of multimedia elements, animation, and application of random parameters and the inclusion of communication between the assessment engine and the multimedia element expand the available method of asking and answering a question and offer valuable opportunities to enhance student learning through formative assessment. More research on enhancing the validity and reliability of e-assessment, especially summative one, is expected to undergo significant change over the coming years.

Formative e-assessment helps students to reflect on their own learning (Pachler et al. 2010). Black and William (2009) proposed five key strategies for implementing successful formative e-assessment in the classroom: design effective questions and learning tasks that measure learning outcomes, provide feedback, share learning intentions and criteria of success, treat students as responsible for their own

learning, and make students learning resources for one another.

Online quizzes and assignments are widely implemented in various subjects' courses in higher education. They take different forms and are implemented in a variety of modes. Instructors choose the appropriate mode that motivates their students. Butler et al. (2008) studied the differences between online quizzes and its traditional counterparts and its effect on students' performance. Immediate feedback provided by the online assessment and the possibility of students attempting the same quiz multiple times is considered one of the main advantages of online quizzes. They also claimed that students obtained higher quiz averages; this indicates that students used immediate feedback to review before trying the quiz again. This influenced their performance and learning of the course. Hirsch and Weibel (2003) concluded that online assignments may motivate students to attempt problems and questions multiple times to give them a chance to correct their mistakes. Feedback can be more effective if it is understood by students, whether it is from a computer or humans. Moreover, instructors could use the feedback to revisit concepts where students had difficulties with while solving the assignments. Developing online quizzes and assignments is time-consuming and requires resources, but it is worthwhile and of valuable benefits.

Feedback enhances students' understanding, skills, and self-learning. In e-assessment, feedback consists of the grade achieved and specifying the questions that students answered correctly and incorrectly. Students could monitor their own learning and discover their strengths and weakness. Feedback could be from their peers and/or their instructors (Carless 2012). Electronic feedback promotes collaboration between students and exchange of ideas and also helps students to analyze their own performance and achievement and reflect on their overall work. Vardi (2012) concluded that computerized assessment with immediate written feedback and automatic marking benefits students' learning. The given feedback should have motivational nature and not too many comments and hints.

Implementation of E-assessment in the Classroom

In the classroom, e-assessment can be implemented in online as well as blended courses through stand-alone computers or networks where distance learning is required.

Various tools, softwares, and learning management systems (LMS) have been used for e-learning and e-assessment, such as Moodle, where secure and simple assessment can be conducted. According to Wheeler (2001), implementing IT in the classrooms will make some forms of assessment, such as traditional testing, redundant and unnecessary and replaced by computer-based testing.

There is sufficient evidence that using information technology (IT) in education helps in changing classroom learning environment from teacher-centered to student-centered and supports collaborative, communicative, productive, and project-centered learning environment as well (Firmin and Genesi 2012). When integrated effectively in classroom learning and assessment in combination with traditional resources and techniques, IT can provide the best classroom environment (Kennewell et al. 2008).

The way of using e-assessment in the classroom and students' experience and perceptions about it have been reported in literature (Miller 2009). Van der Pol et al. (2008) studied how students receive the online feedback from their lecturers and peers. Integration of interactive questioning and discussions into the learning environment and its impact on enhancing students' self-learning abilities have been reported (Nix and Wyllie 2009).

Students' Perspectives on E-assessment

The majority of students find e-assessment programs beneficial to their learning, according to Jiao (2015). Research showed that students see assessment as part of their learning which can be practiced by themselves or their peers (Rastgoo et al. 2010). Dermo (2009) measured the perceptions of students toward e-assessment. His study

revealed that students think positively about e-assessment. Sorensen (2013) study concluded that e-assessment engages students more, and they see it of added value. Other studies (Gotlib et al. 2015; Petrisor et al. 2016) showed that students prefer e-assessment over traditional ones.

Security and Dependability in E-assessment

Dependability includes various aspects, such as availability, reliability, safety, integrity, and maintainability. The success of electronic examination systems is influenced by other security requirement factors, such as prevention of cheating.

The extent to which an examination system is ready, available, for use is essential to holding exams, especially large-scale examinations, as sudden breakdown may occur or students might try to knock it down if they fear to fail. Holding the examinations at university test centers and using redundant hardwares were suggested by Weippl (2005) as a way of increasing availability.

Delivering a correct service and reliability, with respect to all test versions as well as grading, is essential to the success of e-assessment. Automatic grading of language responses with fair reliability has always been a challenge to e-assessment. The random selection of questions to create various exam versions has to be adjusted to make sure that all versions are reliable and have comparable levels of difficulty. If the system does not check for validity of students' answers of free text questions, we might see problems with the system, as they might write symbols the system does not recognize (Howard and LeBlanc 2002).

There are very few security risks involved when we implement e-assessment, as no harm is expected even if all data is lost. Data can always be recovered through backups.

Unauthorized users must not be able to modify the exam questions and students' answers. Data integrity is essential, so before even starting the exam it should be made sure that the questions are not altered and the students' answers will be

stored in an unaltered way. Swiderski and Snyder (2004) stressed on the importance of applying the principle of defense in depth in order to protect system access for unauthorized personnel.

The ability of the system to be modified, updated, and repaired is what we mean by maintainability. Security problems have to be handled fast, and exams have to be tested before installing them on the system.

Advantages and Disadvantages of E-assessment

According to AlSadoon (2017), some of the e-assessment advantages for students, educators, and educational institutions are allowing for evaluating important life skills, improving the quality of tests, raising reliability of grading, reducing time of marking, encouraging students' participation, giving immediate feedback, and reducing printing costs. The effect of using computer-based testing and assessment on students' achievement as compared to traditional paper-pencil ones has been reported by various studies (Chua 2012; Shuttleworth 2009; Yu and Ohlund 2010), with mixed results. Bhatti et al. (2005) concluded that students who are shy to participate in classroom discussions are more active in online ones, since it allows them to show their communication as well as higher-order thinking skills. However, e-assessment has some disadvantages as well; preparing tests is time-consuming, there are worries of dishonesty in e-test taking including illegal help during the test, and technological resources are needed (Rowe 2004). To overcome some of these problems with e-assessment, instructors could use a bank of questions so the test is different for every student, and students may be blocked from viewing their answers after completing the test.

Keys to the Success of E-assessment

Teachers need to properly be trained, supported, and provided with the necessary resources in

order to implement various types of technology in the classroom. According to Quesada-Serra et al. (2014), lecturers must be trained to enhance their competence and skills in order to be able to implement assessment in general. Effective training programs need to be implemented in order to train higher education instructors on e-assessment and learning-oriented e-assessment (Rodriguez-Gomez et al. 2016). They also measured the instructors' perceptions on the importance of the training program they provided on their e-assessment competence and skills, by implementing a mixed method research. Their research showed that instructors' skills were enhanced in assessment planning and design, monitoring of students' learning, participation of students, and improvement of the assessment process in general.

Conclusion

Using information and communication technology in assessing students' learning helps changing the classroom environment positively. E-assessment is now used in many higher education institutions across the world. There are many forms of e-assessment which have been reported in the literature. E-formative and summative assessments have been implemented widely, through various IT tools, such as interactive whiteboards, digital portfolios, tests, authentic or project-based learning, closed questions, product design, and discussion blogs. Formative e-assessment helps students to reflect on their learning. E-assessment can be implemented in online as well as blended courses. Online assignments are used in various courses and subjects in higher education. The main advantage for such tasks is the immediate feedback that students could have, as well as the possibility of students repeating the assignment many times to give them a chance to correct their mistakes. Feedback in e-assessment helps students to monitor their learning and motivates them. Training of teachers and instructors is key to the success of e-assessment implementation. Security and dependability are critical issues in

e-assessment. There are many advantages and disadvantages to be considered when we talk about e-assessment. Some of the advantages are allowing for evaluating important life skills, improving the quality of tests, raising reliability of grading, reducing time of marking, encouraging students' participation, giving immediate feedback, and reducing printing costs. However, e-assessment has some disadvantages as well; preparing tests is time-consuming, and there are worries of dishonesty in e-test taking including illegal help during the test.

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Information Technology for Local Education Authorities and School Districts, Use of

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Synonyms

Educational change; ICT policy plan; Policy enactment; Strategic educational management; Technology leadership

Definition

School technology leadership and strategic educational management are defined on this section as specific conditions for the successful integration of technology from a school-level perspective. When considering these conditions, it is possible to study the interaction with external authorities and organizations at local, district, and national levels. From an organizational and situational perspective, technology leadership can be defined as a distributed practice for setting the vision of ICT integration; as an institutional attribute, it refers to the allocation of conditions to foster educational innovation on different domains. On the other hand, strategic educational management refers to a participatory practice in which organizational complexity is tackled through governability, collaboration, and a shared vision.

The management of educational institutions in a globalized world presents challenges, different from those in previous decades. Therefore, an interconnected environment, supported by new technologies and different information systems that increasingly monitor schools, demands persistent communication with external groups and organizations. For this reason, school leaders and administrators must assimilate a great amount of information that has to be managed, both within and external to the institutions. Different actors with different responsibilities are also involved, and school leaders must identify them competently in their own institution. In this highly complex setting, educational leadership also depends on decision-making related to different areas such as infrastructure, curriculum, and budget. Consequently, it is important to reflect on the main concepts, dimensions, and issues linked to the work of school leaders when they interact with external authorities at a local, district, and national levels.

Part I of this entry describes leadership and educational management as fundamental school-level conditions to foster innovation within and external to an educational institution. Part II analyzes different levels of strategic management, in order to understand how school administrators

should use IT to expand possibilities for innovation beyond the boundaries of classrooms and institutions.

Part I: Leading and Managing Educational Innovation with New Technologies

In the past two decades, literature on school technology integration has focused on different dimensions such as pedagogy, teaching practices, student assessment, and criteria for technology acquisition. In this regard, scholars have devoted less attention to organizational and institutional variables that represent conditions for successful integration of technology (Goodison 2002; Hayes 2007). The community of information and communication technology (ICT) researchers can be divided into those investigating the effects of technology in student performance, those examining ICT integration from a qualitative perspective, and those focusing on conditions at an organizational or school level (Evers et al. 2009).

At the same time, the last group is divided between those focusing on a holistic perspective in order to devise overall models for ICT integration, and those examining the role of a specific condition, such as the characteristics of individual teacher, teacher attitudes toward computers, gender differences, and teacher beliefs. The underlying assumption is that pedagogies and technologies are not enough to foster innovation, as they are intertwined with organizational and institutional variables (Vanderlinde et al. 2011). Even schools with easy access to technology do not necessarily improve teaching practices, as a result of not only ICT teacher competencies but also school-related factors (Cuban et al. 2001).

Considering this last subdivision in the community of ICT researchers, the following segment analyzes two specific conditions for successful integration of technology from a school-level perspective: school technology leadership and strategic educational management. As will be demonstrated, these conditions are necessary to study the interaction with external authorities and organizations at local, district, and national levels.

Leading Innovation with Technologies

The extensive literature on leadership developed in the twentieth century has deployed a set of traditions that are used when studying this concept in organizations. The most established classification identifies a first tradition that relates to individual traits of a single leader; the second tradition relates to leadership styles or behaviors beyond personal characteristics; the third tradition criticizes the aforementioned traditions, because they omit situational and organizational factors. As a response to these traditions, new leadership and relational theories have emerged in the field surpassing the boundaries of administration and psychology. The field of education has been based on these traditions and emerging theories, which emphasize that effective leadership improves learning and institutions (Leithwood et al. 2004).

Scholars assert that successful leadership is related to external interaction with groups, as it will be emphasized in this section: “Much of the success of district and school leaders in building high-performance organizations depends on how well these leaders interact with the larger social and organizational context in which they find themselves” (Leithwood et al. 2004, p. 24). Drawing on empirical research and from an organizational perspective, three practices are identified for achieving successful leadership: setting direction, developing staff, and redesigning the organization (Leithwood et al. 2004; Leithwood and Jantzi 2005).

Following this perspective, some scholars refer to ICT leadership as the practice of setting the vision of ICT integration, fostering ICT teacher development, and providing conditions for access, support, and policies for change within the institutions (Dexter et al. 2002; Zhao and Frank 2003).

Some scholars consider this kind of leadership as the key role of a single individual appointed within an institution. The school leader (Granger et al. 2002), or the ICT coordinator (Tondeur et al. 2008), is responsible for the successful integration of technology. Other approaches refer to the concept of technology leadership as an institutional attribute rather than focusing on an individual. In

this regard, Anderson and Dexter (2000) describe some features at this institutional level:

- An appointed ICT committee (an organized team that has the responsibility for planning, implementing, and evaluating technology integration)
- A financial plan for ICT integration
- The allocation of time for planning ICT integration by the principal
- Economic support from the government
- A concrete ICT teacher-training program

All of these features and practices can be analyzed separately to understand technology integration from an organizational perspective. However, some scholars have preferred to study the complex interaction between these practices and artifacts related to the process of leading innovation through ICT. Related to this, the recent literature refers to the concept of ICT policy plan, a blueprint that shows how an institution integrating ICT for education might look (Fishman and Zhang 2003). Indeed, having a shared vision of ICT integration and an ICT policy plan are key factors that researchers identify as conditions for successful integration at the school level (Hew and Brush 2007). As ICT policy plans can exist on different scales (national, district, or school levels), it is necessary to highlight the alignment and the interaction of the institutional plan on the district and the national levels.

As a very complex artifact, an ICT policy plan embeds different areas or policy domains, including vision development, infrastructure, curricular integration, budget, and teacher training. According to Vanderlinde et al. (2012), what they refer to as ICT leadership is the complex interaction between an ICT policy plan and the leader’s effort to formulate and implement this artifact.

An appropriated ICT policy plan should be based on a complete diagnosis of internal needs and requirements of different areas (infrastructure, curricular integration, teacher training, etc.) aligning a vision and goals to those needs and requirements. Therefore, ICT policy planning

refers to the process of enacting such a plan through different strategies and interactions:

ICT policy planning is a process of developing, revising and implementing ICT plans in order to guide organizations toward broader goals ... situated within Fishman and Zhang's (2003) deeper definition of ICT policy planning ... is defined as a comprehensive school document containing a variety of strategic and operational elements concerning the integration of ICT in teaching and learning (van Braak 2003; Frazier and Bailey 2004). (Vanderlinde et al. 2011, p. 1340)

In this regard, one could say that both the product (ICT policy plan) and the process (ICT policy planning) are fundamental to technology leadership and successful integration. Overall, any attempt to interact with external authorities and organizations implies ICT policy planning, considering the five policy domains described in Vanderlinde et al. (2011):

- ICT vision development
- Financial ICT policy
- Infrastructure ICT policy
- ICT continuing professional development policy
- ICT curriculum policy

Put differently, a school's vision should not be isolated from the external demands of parents, local communities, the job market, etc. Infrastructure should be planned according to key allies and stakeholders in the region that could sponsor institutional improvements. Teacher professional development should be aligned with national guidelines and regulations that school leaders should be aware of. As stated above, school technology leadership, or ICT leadership, implies an effort from a leader and her team to foster innovation through the enactment of all these different domains, an endeavor that necessarily includes external cooperation and negotiation.

Strategic Management for Technology Integration

Typically, leadership and management have been studied as related concepts, even as interchangeable synonyms. For instance, some scholars refer

to change management as an attempt to combine these two concepts (Brown 2013). Conversely, others differentiate leadership as encompassing educational change at different levels, whereas management is linked to the administration of resources of a different nature. The following describes educational management as a second school-level condition for the successful integration of technology, highlighting the complex interrelationship with leadership for educational innovation.

Management of education has usually been linked to administrative issues covering areas such as budget and staffing. Even the reference to the management of technology in educational settings implies the formulation of a financial plan for the acquisition of technology or provision of technical support for the institutional platform. Given the complexity of educational institutions, it is nevertheless important to surpass this simple concept.

Strategic management represents a turning point in the traditional approach of school administration, as it existed in education in the past century (UNESCO 2000). This implied that leading an educational institution was an administrative endeavor. Traditional school administration also assumed a labor division in which directors led the institution technically, whereas teachers were in charge of curricular and instructional practices. This led to the fragmentation of activities and the lack of a shared vision. On this model, the administration was related to teaching (not learning), achieving goals that came from the outside (top-down rationale), causing a lack of interest in the community in pedagogical matters. Indeed, a final result was the separation of administrative activities and pedagogy as two different realms.

Compared with the school administration model, strategic educational management considers pedagogy as the center. As a participatory-oriented model, it focuses on coping with organizational complexity, uncertainty, and conflict, promoting innovation through collaboration. Strategic educational management is related to governability, which is a way to integrate the technical and political aspects of education.

Beyond technical and external “recipes” for general problem solving as previous approaches to educational administration, school leaders have to consider their own particular context; hence, strategic management has to do with governing collectively, inspired by a shared vision and considering the interdependence of actors within and external to the institution (UNESCO 2000).

In general, technology leadership and educational management are usually linked to the internal reality of an educational institution. However, it is important to understand that both dimensions also operate outside the institution. As stated above, technology leadership and educational management imply that school leaders foster innovation from a strategic perspective that involves key actors and alliances from inside as well as outside the institution. In other words, there is no way to strategically lead and manage innovation for change using IT unless a strong collaboration with external groups and organizations is considered. In the following, different forms of strategic management will be considered in relation to ICT policy planning.

Part II: Levels and Conditions for External Interaction

In this segment, different levels and conditions are analyzed as keys to leading and managing IT integration for educational purposes. As will be demonstrated, technology is highlighted as a means and an end. As a means, technology can support communication processes to establish fluent interactions with different actors at each level. As an end, technology is a matter of leadership and management fostering innovation within educational institutions. Three different levels can be distinguished when considering the strategic management that a school leader has to deal with.

Depending on the political and administrative organization from each country, the levels can be named differently. So, the first level of interaction is the *local*. It embeds permanent communication with the mayor’s office, parents, and other actors

that benefit from the educational institution. The second level is the *district*. In some countries, this level is also considered as zones or departments; in other settings, it can be provinces composed of municipalities. The third level is the *national* that, once again, will be considered differently if there is a federal or centralized administration in a particular country.

These three levels encompass different and complex relationships with the public and private sectors. Put differently, external relationships will be different if an institution receives subvention from the private sector based on its geographical location. Conversely, a municipality that has to share public funds among all educational institutions will establish a different set of relationships and competition for budget.

So, it is also important to make different statements when considering if a school belongs to the public or private educational system. The level of autonomy must be considered. In other words, autonomy can vary if an institution depends on national or district resources from the government, or if an institution that depends on tuition fees, because it is private.

An additional contextual factor is the type of educational institution. Different types of institutions encompass particular visions with specific educational goals. For instance, some institutions offer technical training to develop specific competencies for the job market. Other institutions offer a more traditional or classical education, based on general competencies that guarantee access to tertiary education. For instance, in the curricular domain of these two types of institutions, leading and managing technology integration will be substantially different based on their educational vision and goals.

Considering the previous conditions, three types of strategic educational management can be identified when considering the integration of technology. As stated above, these types of management are related to ICT policy planning, whose purpose is to enact a vision of how education can be fostered when integrating technology. In fact, these types are closely linked to the different domains embedded in an ICT policy plan (ICT vision development, financial ICT policy,

infrastructure ICT policy, ICT continuing professional development policy, and ICT curriculum policy). The following highlights the external relationships for the domains at the local, district, and national levels:

Financial management. Considers the allocation of budget for the acquisition of products and services declared in the ICT policy plan. Although it is difficult to declare a priori the key areas for investment, because it depends on the institutional diagnosis and the identification of needs, the most common areas regarding technology integration are devices and Internet supplies. Nevertheless, strategic management should also link teacher training to the financial plan, because it increases a successful integration of technologies for enhancing teaching and learning. A key practice for leaders is the involvement in the call for bids from both the government and the private sectors, because they are opportunities to sustain educational innovation initiatives. School leaders should seek external guidance for building their institutional budget considering that some public and private organizations offer this technical knowledge. Key questions for school leaders in this area are related to the following questions: where and how to identify the stakeholders and other key sponsors at the local and district levels? What kind of government grants can support the financial plan? Is there a chance to collaborate with other institutions for acquisition of technology at a low cost from the private sector?

Infrastructure management. Refers to the acquisition of technology, facilities, and conditions for technology integration, such as Internet services and supplies. As a rule of thumb, infrastructure acquisition will not be successful unless technical support is included in the ICT policy plan. Put differently, the investment in technology and facilities has to be planned for the long term, given that obsolescence and user interaction must be considered when planning and managing technology in the institution. School leaders, then, should find a first key

interaction on the national level with the ministries of education, communication, or technologies (depending on the country). Locally, the communication with the mayor's office is pivotal, because many authoritative regulations are on behalf of this actor. A school leader should guarantee that an institutional diagnosis includes a precise analysis of infrastructure requirements, involving as many staff as possible (once again, in a participatory fashion), and base his leadership on questions such as the following: what kind of technological devices, services, and technical support will fulfill the needs to achieve institutional goals?

Curricular and pedagogical management. Considering that strategic management is situated in educational institutions and considering the turning point from a school administration approach, this last type of management highlights curricular and pedagogical matters. Evidently, the ministry or department of education at the national level and the provincial and mayor's offices at the local level become critical allies for any kind of initiative on a curricular level. Integration of technology in the curriculum represents a challenge that surpasses the acquisition of devices for each classroom. Instead, professional development for teacher should include a deep analysis of instructional design across different areas of knowledge. The alignment with district or national guidelines should be included in such curricular analysis, as well as learning assessment standards. A key question for school leaders could be the following: what kind of strategic alliances can guarantee the improvement and quality of the pedagogical model?

Conclusion

This section has demonstrated that technology leadership and strategic educational management represent two key dimensions, for both successful technology integration within an institution and for the interaction with external

authorities and organizations. Although both concepts have been studied vaguely by some scholars, they were described here as two singular practices that are intertwined when considering the kind of issues that school leaders have to deal with.

Leadership has been identified in the literature as a key variable for successful performance in student learning (Leithwood et al. 2004). Nevertheless, school technology leadership, or ICT leadership, has only recently received attention by scholars as one of the conditions for successful ICT integration. The practice of interacting collaboratively with internal and external actors to enact a vision of technology integration through artifacts, such as an ICT policy plan, is only possible from a distributed approach to leadership (Vanderlinde et al. 2011). In other words, leadership is not a matter of individual charisma but the orchestration of a set of relationships that embeds persons, artifacts, and interactions on different scales.

Similarly, the emphasis in educational management has changed from an administrative approach to a strategic one, in which financial and infrastructure have to be oriented by pedagogical matters. These types of management depend on a team-oriented management that surpasses the practice of a single individual. As was demonstrated, collaborative work is necessary to establish communication with external organizations. All in all, these three types should be guided by key questions such as the following: what kind of external cooperation and alliances are more suited to the declared vision? So, school leaders should strategically identify the authorities and organizations that can act as a lever for the enactment of such an institutional vision.

Although the analysis has centered on fostering technology integration for educational purposes, it is also relevant to underscore the fact that technology itself can be used as a lever for the enhancement of leadership and management when interacting with external authorities and organizations (as stated above that IT can be the means of working with authorities and organizations, not only as an end).

A first example can be located on information system platforms for administrative purposes. Many different countries are using these sites at national and district levels to centralize information on school enrollment, student dropout, and the management of administrative and teacher staffing. Although every institution can administrate its own information system platform, nowadays it is more common for external authorities, such as ministries or departments of education, to manage these platforms in order to monitor institutional performance and administrate national or district budgets.

A second example from the academic point of view includes learning management systems (LMS), frequently used as sites for instructional and pedagogical purposes. Although the interaction between teachers and students is the most common and relevant use of these LMS, school leaders can also trace evidence of teaching and learning practices to supervise educational practices. These platforms can also be useful for pedagogic management of national standards for learning assessment or curricular alignment.

A final illustration of using technologies for interacting with external groups are institutional webpages and social networks as they represent a strategic tool for external communication and diffusion of innovations. On a local level, parents are the first target of these institutional webpages. However, for strategic promotional purposes, these tools are used increasingly by school leaders who look for potential stakeholders of different initiatives for innovation. Another strategic purpose of social networks that has also been increasingly adopted is related to establishing networks and communities of learning of different types and for different audiences (principals and teachers and the most frequent users).

Overall, IT as a means to enhance technology leadership and strategic management implies the development of digital competencies in those school leaders and their teams to integrate technology for educational purposes. Along with those competencies, this section has also demonstrated the relevance of teamwork and negotiation

as necessary to increasing interaction on the local, district, and national levels.

Summary

This section refers to the work of school leaders when they interact with external authorities at a local, district, and national levels in relation to the use of information technologies. Considering an organizational and situational perspective, the role of leaders interacting with other members in order to enact an ICT policy plan represents a key factor for successful integration of ICT. Five different policy domains embedded on this ICT policy plan explain the necessary interaction between leaders and external authorities and organizations. Put differently, a school's vision should not be isolated from the external demands of parents, local communities, the job market, and others. Following the same organizational perspective, this article defines strategic educational management as a collaborative practice able to cope with organizational complexity, uncertainty, and conflict. Different levels and conditions are analyzed as keys to leading and managing IT integration from this model. On this regard, three types of strategic educational management can be identified when considering the integration of technology: financial management, infrastructure management, and curricular and pedagogical management. By last, the article considers that technology itself can be used as a lever for the enhancement of leadership and management. In other words, IT is depicted as the means of working with authorities and organizations, not only as an end for the promotion of educational innovation.

Cross-References

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Innate Abilities and Learning in Higher Education

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Big five personality traits; Culture; Higher education; Learning; UAE

Learning Models

The ever-lurking question that has always engaged educators is what drives students to effectively learn and excel. In their review of the literature, Zhang and Ziegler (2016) reported that although there is a plethora of cognitive, personality, and other narrower traits that contribute to student performance however, meta-analyses have always shown that personality traits that are based on the Big Five (BF) factor model (in particular openness and conscientiousness

where conscientiousness was the most powerful predictor across the secondary and tertiary levels followed by openness) contribute to the prediction of student success above and beyond intelligence. The BF are five important factors that are used to describe human personality and behavior, and it is indicated to capture most of individual's daily differences in behavioral patterns and performance in many domains (Babakhani 2014; Costa and McCrae 1992; De Feyter et al. 2012; Graham 2006; Kinga et al. 2012; Lynn 2009). They are:

- (a) Extraversion refers to the extent to which a person is sociable, talkative, lively, active, adventurous, openness to experience, creative, imaginative, and excitable (Peetsma and Van der Veen 2011). Also, extraversion reflects a tendency to like people, prefer being in large groups, and desire excitement and stimulation (Digman 1990).
- (b) Conscientious students are characterized by their orderly, un-superficial, and precise manner of working which strongly enhances performance during assessment (De Feyter et al. 2012). Conscientiousness reflects a tendency to be purposeful, organized, reliable, determined, and ambitious (Digman 1990). Thus, a person who is high in conscientiousness would make an effort to be careful, organized, responsible, and able to persist at a tedious task for a longer duration than people lower in conscientiousness.
- (c) Agreeableness is characterized by being altruistic, cooperative, and trusting (Digman 1990). Agreeableness is the extent to which a person is good-natured, helpful, trusting, and cooperative. People who score high on this dimension are empathetic, considerate, friendly, and generous. They also have an optimistic view of human nature. They tend to believe that most people are honest, decent, and trustworthy.
- (d) Neuroticism (emotional stability) refers to the extent to which a person is calm and secure. Individuals who score high on neuroticism are more likely to experience such feelings as anxiety, anger, hostile, guilt, and depressed

mood (Digman 1990). Neurotic individuals are often easily frustrated (Swinton 2010).

- (e) Students high in openness are expected to be curious about new and challenging materials and to be imaginative (Digman 1990). A person who is high in openness to experience would be a creative thinker who is independent and does not like routines, has the desire to engage and understand the world, and involves in different activities (Peetsma and Van der Veen 2011).

In a review of the literature, John and Srivastava (2001) found that the BF identifies individual differences in behavior and experience and they supported the importance of the BF taxonomy as an “integrative function” because it can represent the multifaceted systems of personality description through a common framework. A plethora of research found the BF contributing significantly in explaining individual difference with respect to academic achievement (AA) (Barbaranelli et al. 2003; Jensen-Campbell et al. 2007; John and Srivastava 2001; Lynn 2009). This is attributed to the ability of the BF to provide a common language for self-report and other ratings and can help in reducing the distance among different informants and in enhancing “interrater convergency” (Barbaranelli et al. 2003).

However, the implications here are threefold (Zhang and Ziegler 2016). Initially, the underlying processes concerning such theories are still unclear. Secondly, prior studies have mostly been conducted in Western culture, and hence, little is known about these effects in non-Western cultures. For example, the existing intercultural research indicated that Asian students perform better in school than their Western peers, especially in mathematics and science because Asian students possess higher academic motivation in that they believe in learning through effort rather than innate ability. Finally, the Big Five and its impact on performance seemed to be subject-specific, i.e., conscientiousness and neuroticism were found to be important for mathematics but extraversion to be important for language learning.

Insights from UAE University

Information about UAE’s society and culture can be drawn from (UAEInteract.com). The United Arab Emirates was established in 1971 and is a constitutional federation of seven emirates: Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al-Qaiwain, Ra’s al Khaimah, and Fujairah. Despite such modernizing effects, the traditional society of the UAE is still uniquely interconnected and resilient. This is reinforced by strong family, religious and tribal ties as well as traditional values of hospitality, cooperating, and sharing. Islam is the common religion and is the base to fortify the UAE society together.

United Arab Emirates University (UAEU.ac.ae) is in Al Ain city. UAEU has nine colleges. As UAEU is a federal university, it serves all the emirates in the UAE, but in the past few year, most of the emirates had their own local and federal universities and institutions, and accordingly, the UAEU coverage started to be limited to few emirates as the research results will show below.

Big Five Personality Traits

Extraversion

Students showed overall average but interesting extraversion behavior (Table 1). Most notably Extraversion2 and Extraversion4 scored the highest in this context which indicates that students don’t like seclusion and always find new ways in order not to get bored respectively.

Such high scores as contrasted with the remaining items suggesting that such students are, on average, happily and lively, like to do activities and conservative respectively. This could suggest here that such students are passing

Innate Abilities and Learning in Higher Education, Table 1 Personality traits – extraversion

Item	Mean	Std. deviation
Extraversion4	4.10	0.868
Extraversion2	4.09	0.898
Extraversion5	3.84	1.006
Extraversion1	3.72	0.996
Extraversion3	3.59	0.998
Overall averages	3.87	0.95

their academic life with the average “extraversion” traits. One interpretation for such differences in opinion could be attributed to UAE’s culture and conservative society. This assertion is worth for further investigation in future research.

Overall, the findings suggested that students are of moderate extraversion nature.

Agreeableness

As noted in Table 2, most results were toward the higher end of the scale. Most notably, Agreeableness1, Agreeableness2, Agreeableness4, and Agreeableness5 were the highest. Toward their peers, this shows that students are more helpful during the class session, affectionate, considerate, and honest, respectively. In contrast, such students seemed to averagely like giving gifts or trusting others. This finding is worth for further investigation in future research.

Overall, the findings suggested that students are of agreeable nature.

Conscientiousness

As noted in Table 3, interestingly, Conscientiousness1, Conscientiousness2, and Conscientiousness3 scored just above the average, and Conscientiousness4 was almost close to the average. This shows that UAEU students are organized, persistent, careful, and focused, respectively.

Overall, the findings suggested that students are of average conscientiousness nature.

Neuroticism

As shown in Table 4, most results seemed to slightly negate such emotional characteristics

of neuroticism and, hence, reflect a more emotionally stable students. Neuro5 scored the highest average here, and this shows that students could moderately (slightly above average) feel guilty if they commit a slight mistake. The remaining variables had lower scores, and this indicates that UAEU female students are usually not depressed, less anxious when arguing with others, they don’t get angry, and lose their calmness easily.

Overall, the findings suggested that UAEU’s students were not of a neurotic nature.

Openness

Overall students performed above the average on this variable (Table 5). Open2, Open5, and Open6 had scored the highest which indicate that UAEU students are open to other cultures, like to learn about new things and imaginative, respectively. Students scored moderately on the remaining items (variety of experiences, independence, and creative thinking) which may point again to the above discussion about cultural perspective of such (female) students. The lower score of Open1 compared to Open5 may suggest a contrast here. This could be justified on the basis that students showed a likeness (openness) toward learning new things despite their moderate knowledge about many things. This resembles a positive

Innate Abilities and Learning in Higher Education, Table 3 Personality traits – conscientiousness

Item	Mean	Std. deviation
Conscientiousness3	3.69	1.044
Conscientiousness2	3.61	1.051
Conscientiousness1	3.50	1.182
Conscientiousness4	2.98	0.915
Overall averages	3.45	1.048

Innate Abilities and Learning in Higher Education, Table 2 Personality traits – agreeableness

Item	Mean	Std. deviation
Agreeableness5	4.44	0.764
Agreeableness4	4.25	0.905
Agreeableness2	4.11	0.899
Agreeableness1	3.90	0.943
Agreeableness3	3.77	1.070
Agreeableness6	3.37	1.059
Overall averages	3.97	0.94

Innate Abilities and Learning in Higher Education, Table 4 Personality traits – neuroticism

Item	Mean	Std. deviation
Neuro5	3.58	1.249
Neuro3	2.63	1.208
Neuro4	2.58	1.226
Neuro1	2.45	1.162
Neuro2	2.41	1.135
Overall averages	2.73	1.196

Innate Abilities and Learning in Higher Education, Table 5 Personality traits – openness

Item	Mean	Std. deviation
Open6	4.16	1.090
Open5	4.11	0.909
Open2	3.91	1.009
Open3	3.58	0.827
Open1	3.55	0.881
Open4	3.35	1.052
Overall averages	3.78	0.961

Innate Abilities and Learning in Higher Education, Table 6 Overall means of the different items

Item	Mean	Std. deviation
Agreeableness	3.97	0.94
Extraversion	3.87	0.95
Openness	3.78	0.961
Conscientiousness	3.45	1.048
Neuroticism (item worded negatively)	2.73	1.196

attitude here. Open3 indicates that students moderately understand what they take in the classroom. This calls for investigating this issue further by any future research. Spending more effort by different pedagogy stakeholders to enhance and enrich student learning inside the classroom is highly envisaged here.

Overall, the findings suggested that students are on average (based on Open1, Open2, Open3, Open4) open in nature. Finally, Table 6 shows the overall means of the different items in this article. Accordingly, it could be argued here that overall, agreeableness, extraversion, openness, and conscientiousness, respectively, were the most important strategies adopted by students. Neuroticism scored the lowest mean average, and hence, students negated being of a highly neurotic nature.

Conclusion

Table 7 summarizes the article's findings and implications and discussed next.

This entry has theoretical as well as professional contributions and contentions. At the theoretical level, we have seen how the BF personality traits have assisted in identifying the innate of CIT students. Although it was not possible to elucidate the significance of the research factors on student's success as such, the BF personality traits shed interesting insights and contrasts on students' personal traits. Findings from this entry suggested that the learning strategies of CIT student were average. The highlighted contrasting views and the dominance of most responses around the average further suggested this posture. This could be attributed to personal as well as to cultural reasons as highlighted in this entry. Many of the suggested enhancements (Table 7) could be achieved by designing programs aiming at enhancing student's learning abilities by boosting their personal innate. However, it is the cultural aspects that are more difficult to unveil and address. Cultural issues require the cooperation and collaboration of the university and the community that surrounds learning in general and the family more specifically. This is an important future research area.

At the professional level, different suggestions were made to enhance student's learning strategies in CIT (Table 7). The expected outcome of this entry will be of importance to researchers, professionals, and policymakers interested in addressing weak and strong learning abilities. This is an initial research in this area in UAE, and indeed, other researchers and universities might be interested in understanding the personal innate of their (IT or others) students. Researchers could further use the suggested factors or add to them and test their significance on their students. Professionals would capitalize on many of the implications in Table 7 to design and offer more focused training programs and workshops aimed at students and officials in universities and elsewhere. Policymakers in higher education institutions could consider many of the suggestion made in this entry to devise more focused and effective policies to enhance student learning strategies.

In discussing other limitations, the dominance of females in the sample could have biased the research results toward raising female's personal

Innate Abilities and Learning in Higher Education, Table 7 Findings and implications

#	Factor	Findings	Implications and suggestions
Big Five personality traits			
1	Extraversion	UAEU's students are of average extraversion nature	Enrich the lives of students in campus beyond learning through, e.g., engaging students in social activities, sports, behavior seminars/workshops "games," personal and teambuilding, etc. Introducing IT concepts like edutainment could further entice learning
2	Agreeableness	UAEU's students are of agreeable nature	Endorse liking and trusting of others, i.e., beyond a student's closed circle of friends. This could be boosted by introducing more teamwork tasks with members' selection being randomized. Also, virtual teams or games could also lower student guards toward others and building trust by focusing on the task not the person
3	Conscientiousness	UAEU's students are of average conscientious nature	Boosting students learning capabilities on/off campus in a way to consider their studies very seriously. This could be done through seminars and workshops. Also, using electronic calendars and organizers could help students manage their different educational tasks and deliverables, etc.
4	Neuroticism	UAEU's students are not of a neurotic nature	Encourage a spirit that rewards achievements and remedy in the case of failure (avoid punishment totally), i.e., trial and error and learning from our mistakes Conducting workshops and seminars to further build students' moral and mental well-being
5	Openness	UAEU's students are of average open nature	This falls again with the suggestions made in extraversion in enriching the students' lives even inside the classroom. In addition to group activities and in promoting student's independence, we may focus on building the student's individual capabilities by giving more individual assessments, i.e., tasks like developing a personal web page, develop a mobile (e.g., personal) smart application, assemble a computer, write a report about a trendy IT topic, etc.

innate and social and cultural behavior vis-à-vis male students. Although the representation of female students in CIT is much higher than male students, future research could increase the male contribution or introduce more complex statistical tools to look for significant differences or commonalities between female and male students. More statistical analysis could look for reliability, validity, correlations of research factors/items, and how they impact student's AA (i.e., GPA). This entry attempted to provide plausible interpretations of the survey findings, but they are inconclusive statistically, and any future research could further take this issue onboard. Such issues could be complemented with more confirmatory quantitative or qualitative research.

The Big Five factors proved their usefulness in capturing most of the important issues pertaining to the personality of CIT students. In contrast,

other researchers started to criticize the BF (Barbaranelli et al. 2003; John and Srivastava 2001; Vedel 2014) pointing to the absence of a common framework to interpret the results and the agreement on the nature and the number of dimensions needed to describe personality (Barbaranelli et al. 2003). The BF do not represent a particular theoretical perspective per se but rather were derived from analyses of the natural-language terms people use to describe themselves and others (John and Srivastava 2001). Others highlighted that personality traits are as highly relevant predictor of AA as cognitive abilities, but the importance of abilities stems from what we actually do with them (Vedel 2014). Others used the BF factors as concurrent predictors of AA and of externalizing and internalizing problematic behavior syndromes (Barbaranelli et al. 2003). Therefore, it would be interesting to extend

the power of the BF with more important strategies and attempt to investigate their importance on students' learning strategies by any future research. This would be the next phase of this project.

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Institutional Repositories Versus Learning Object Repositories, Challenges and the Way Forward for Higher Educational Institutions

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Synonyms

[Container](#); [Cyberlearning](#); [Depository](#); [Digital object library](#); [Educational material](#); [Electronic library](#); [Graduate school](#); [Information superhighway](#); [Instructional materials](#); [Locker](#); [National Information Infrastructure](#); [Online scholarship](#); [Philomath](#); [Receptacle](#); [See closet](#); [Teaching material](#); [Tertiary school](#); [Training material](#); [Treasury](#); [Virtual library](#)

Introduction

The setting up of institutional repositories and learning object repositories in this digital age is part of the struggle of many higher educational institutions to achieve E-scholarship: a technology-enabled environment for the discovery, creation, and preservation of digital resources for purposes such as research, teaching, and learning. These repositories are believed to have great potential to address a number of pressing challenges of access, equity, quality, and productive scholarship in tertiary institutions.

However, while many institutions have shown the impact of growing IR content, many IRs continue to struggle to show sustained growth (Marsh 2015). Lynch recently addressed this stagnant growth by asking, “Is it important for institutions to maintain a local comprehensive record of their scholarly output through their IR?” (Lynch 2017: 127). Because most institutions routinely create intellectual content for a world of information-seeking audiences, these questions of stagnating IRs and whether or not the institution needs a local collection of its scholarly record are considered very interesting (Bull and Schultz 2017).

Chan (2004) indicates that some proponents of the open-access movement see the institutional repositories (IRs) or the open-access archive as the most cost-effective and immediate route to providing maximal access to the results of publicly funded research, thereby maximizing the potential research impact of these publications. Some research libraries see IRs as a means to expand the amount and diversity of scholarly material that is collected and preserved, thus enhancing teaching, learning, and research at the host institution and beyond (McCord 2003). Some see IRs as a way to enhance an institution's prestige or branding by showcasing its faculty's teaching and learning output (Crow 2002). On the other hand, others see IRs as an essential infrastructure for the reform of the entire enterprise of scholarly communication and publishing (Guédon 2003), while a learning object repository (LOR) is a collection of LOs having detailed information (metadata) about

them that is accessible via a network or the Internet. In addition to housing LOs, repositories can store “locations” for objects that are held elsewhere (The JORUM 2005: 11). Whichever way experts look at it, the fact remains that both institutional repositories and learning object repositories are ways of showcasing and promoting higher educational institutions’ teaching and learning output.

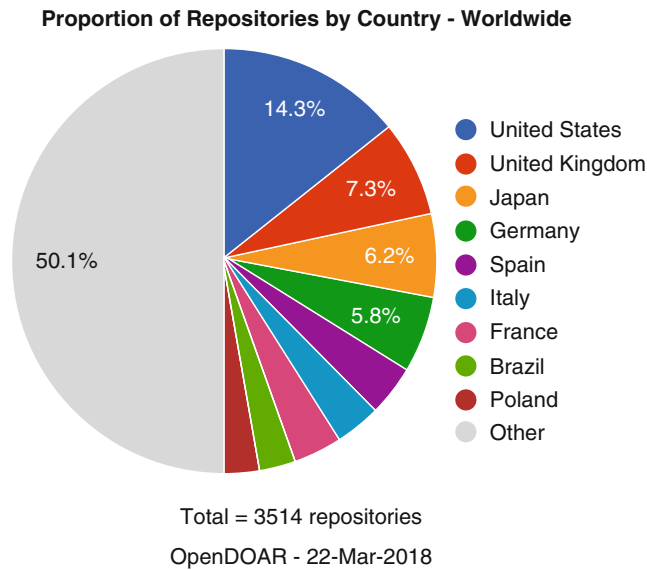
Institutional repositories (IRs) and learning object repositories (LORs) have increasingly been deployed in academic institutions to organize, preserve, access, and facilitate the use of digital content produced by members of their communities. Figure 1 shows the repositories’ growth over time, while Fig. 2 shows the proportion of repositories by countries worldwide. There are various definitions of IRs (e.g., Branin 2005; Crow 2002; Lynch 2003) however, for this entry adopts a broader definition which sees IRs as a higher education-based set of services offered to members of its community for the management and dissemination of digital materials created by the institution and its community members. Learning object repositories on the other hand are simply viewed as places to put digital objects. Similarly, a learning object repository is a system supporting a community working together to share and reuse

resources for learning. A central repository would be one that stores the objects for a defined community or organization. As objects can vary in number, size, and file type, it is unlikely that a single central repository would be able to collect or even physically hold all of the available learning objects in any given field (Hamilton 2001). Learning object repositories have the ability to share information and exchange records about learning objects and provide access to the objects themselves.

Figures 1 and 2 contain the proportion of repositories by countries worldwide for March and October 2018 (Saini 2018; Luther 2018). The deployment of IRs and LORs in the academic sector is an international phenomenon. Figures 1 and 2 also testify to this.

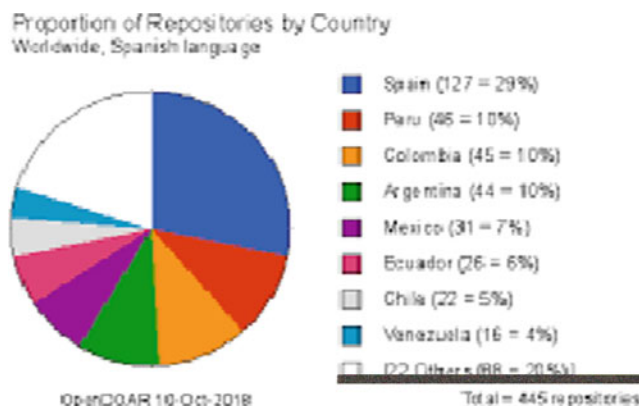
The USA maintains the highest percentage, i.e., 14.3% (3514), of the number of repositories maintained by the academic libraries in their higher education system in OpenDOAR as of March 22, 2018. This also shows the dominance of the USA over other countries for the creation and management of the IRs. The UK is the second leading country with 10.88% (136) of repositories. The UK shares 7.3% of total repositories registered on OpenDOAR also as of March 2018. However, the story changed in OpenDOAR (2018) report on the same data with now taking

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Fig. 1 Proportion of repositories by countries worldwide. (Source – Saini 2018)



Institutional Repositories Versus Learning Object Repositories, Challenges and the Way Forward for Higher Educational Institutions,

Fig. 2 Proportion of repositories by countries worldwide. (OpenDOAR 2018: 4)



the lead with 29% of the 445 repositories, followed in declining order by Peru with 10% of the 445. Surprisingly, the USA and UK that led in the March edition of the data are now conspicuously missing.

The van Westrienen and Lynch (2005) survey results reveal great diversity among IRs. In some countries, such as Germany, Norway, and the Netherlands, IRs have already become a common infrastructure in academic institutions. In Finland, IRs are just getting started; in Norway, 90% of the current IR records are for books and theses; IRs in France tend to have more articles; and Australian IRs have more primary sources data than those in other countries (Van Westrienen and Lynch 2005). Van Westrienen and Lynch also found that European IRs have been aided by national policies and other activities that promote the development of IRs. To buttress the above, JISC (2008) reports that “more and more IRs are being set up worldwide, with details of these being found in the Registry of Open Access Repositories (ROAR) or the Directory of Open Access Repositories (OpenDOAR).” Evidently, this is now confirmed with Saini (2018) and OpenDOAR data released in March and October 2018, respectively. The report by Westrienen and Lynch (2005) states further that 16 of the 19 top

UK research-led universities of the Russell Group have now set up IRs, while the SHERPA (Securing a Hybrid Environment for Research Preservation and Access) project has helped establish IRs in 20 institutions, including the universities of Oxford, Nottingham, and Edinburgh. Significant efforts were also noted in many Asian countries, e.g., Japan, China, and Taiwan, in the creation of IRs and LOR. In Taiwan, LOR is designed for teachers instead of students. Moreover, an increasing number of organizations are actively supporting the establishment of IRs, and a UK Parliamentary Committee has explicitly encouraged the creation of IRs in a select committee. Depositing work in an IR is increasingly being regarded as a way of maximizing the control exercised over how research is disseminated and accessed. With these reports and other evidence, it is now glaringly obvious that both institutional repositories and learning object repositories are in the vogue. have also observed that over the past year it has become apparent that the field of learning object repositories (LORs) is of considerable national and international interest. In the light of this, this entry examines the institutional repositories and learning object repositories in terms of their similarities and differences, the types of content found in them, the likely policy

guiding implementation, the challenges faced by higher educational institutions in setting up and implementing these repositories, and the possible way forward.

Institutional Repository

According to Crow (2002), “institutional repositories represent the logical convergence of faculty-driven, self-archiving initiatives, library dissatisfaction with the monopolistic effects of the traditional and still pervasive journal publishing system, and the availability of digital networks and publishing technologies.” Drake (2004) pointed out that repositories provide services to faculty, researchers, and administrators who want to archive research, historic, and creative materials. The open-access and open-archives movement, the need for change in scholarly communication to remove barriers to access, and the increasing awareness that universities and research institutions are losing valuable digital and print materials have begun to drive the establishment of institutional repositories. Crow (2002), in a Scholarly Publishing and Academic Resources Coalitions (SPARC) position paper, adds that IRs are digital collections capturing and preserving the intellectual output of a single or multi-university community. Crow emphasizes that repositories of an institution are important for two major reasons:

1. They are natural extensions of the academic institution’s responsibility to generate primary research, seeking to preserve and leverage its constituents’ intellectual assets.
2. They are a major component in the evolving structure of scholarly communication.

In addition, Otando (2010) identified another four. These are:

1. Enhancing and advancing the process of scholarly communication
2. Preserving the intellectual output and memory of the institutions

3. Increasing visibility of the parent institution and the profile of the researchers
4. Increasing the ranking of the institution in research and scholarship

Drake (2004) emphasizes that while the main purposes of institutional repositories are to bring together and preserve the intellectual output of a laboratory, department, university, or other entity, the incentives and commitments to change the process of scholarly communication have also began serving as strong motivators. Repositories may be limited to one field, one department, one institution, or a consortium of several institutions. However, collaboration through a consortium reduces costs for each member through resource sharing while expanding access to digital materials.

The characteristics of institutional repositories conceived by Crow (2002) include the facts that it:

- Provides a critical component in reforming the system of scholarly communication – a component that expands access to research, reasserts control over scholarship by the academy, increases competition and reduces the monopoly power of journals, and brings economic relief and heightened relevance to the institutions and libraries that support them
- Has the potential to serve as a tangible indicator of a university’s quality and to demonstrate the scientific, societal, and economic relevance of its research activities, thus increasing the institution’s visibility, status, and public value

Furthermore, Henry and Anderson (2005) add to the list of institutional repositories characteristics by indicating that:

- A repository contains *content*, deposited by the owner, the creator, or a third party.
- A repository architecture manages content as well as *metadata*.
- A repository offers a minimum set of *basic services*, e.g., put, get, search, and access control.
- A repository must be *sustainable* and *trusted*, *well-supported*, and *well-managed*.

- If an open-access repository, it must also:
 1. Provide open access to its content (notwithstanding legal constraints)
 2. Provide open access to its metadata for harvesting

Crow (2002) outlines the attributes of institutional repositories to include the fact that content is scholarly in nature and digital in format, employs self-archiving methods, has open access, and is interoperable and managed by individual academic communities and the research library.

An institutional repository contains diverse intellectual output of an institution that may include the following:

- Preprints of articles or research reports submitted for publication
- The text of journal articles accepted for publication
- Revised texts of published work with comments from academic readers
- Conference papers
- Teaching materials
- Student projects
- Doctoral theses and dissertations
- Datasets resulting from research projects
- Committee papers
- Computer software
- Works of art
- Photographs and video recordings
- Materials documenting the history of the institution or area

Drake (2004; Luther 2018; Saini 2018; Aguillo 2018) offers some examples of institutional repositories around the world; these include but are not limited to:

1. DSpace is an open-source digital repository system from the MIT Libraries and Hewlett Packard Labs and is mainly an example of archiving software (e-prints and other scholarly artifacts).
2. The University of California's eScholarship Repository (<http://repositories.cdlib.org>).
3. The developers of the Ohio State University (OSU) Knowledge Bank (<http://www.lib.ohio-state.edu/Kbinfo>).

4. **FEDORA** (Flexible Extensible Digital Object Repository Architecture) began as a DARPA- and NSF-funded research project at Cornell University.

5. **EPrints** – EPrints is often used as an institutional repository and has the largest installed base of any repository system. EPrints was developed at the University of Southampton. It provides a web interface for managing, submitting, discovering, and downloading documents.

As indicated by Luther (Fig. 3) in a study conducted in North America in 2018, most of the IR systems available today are community-developed open-source software (such as DSpace, Islandora, Samvera, etc.), which is consistent with the values and culture of institutions implementing IRs. Larger libraries with technical staff prefer to customize software, while smaller libraries depend on a service model (such as Digital Commons) that provides IR and publishing capabilities with less impact on staff requirements. Recent growth among smaller institutions favors a service model. The Directory of Open Access Repositories (DOAR) indicates that DSpace and Digital Commons (bepress) are the most widely held in North America. As the software begins to mature, libraries have access to more functionality which offers opportunities to introduce new services or consolidate platforms.

It is now clear from the examples that institutional repositories and open archives are being established worldwide. Many institutions use GNU e-print software for these projects. Other newly developed institutional repositories are CiteBase, OAI (Open Archives Initiative), BOAI (Budapest Open Access Initiative), Paracite, RCHIVESIC, AURA (Aberdeen University Research Archive), ERPANET, eDoc Archival, eBank UK, etc.

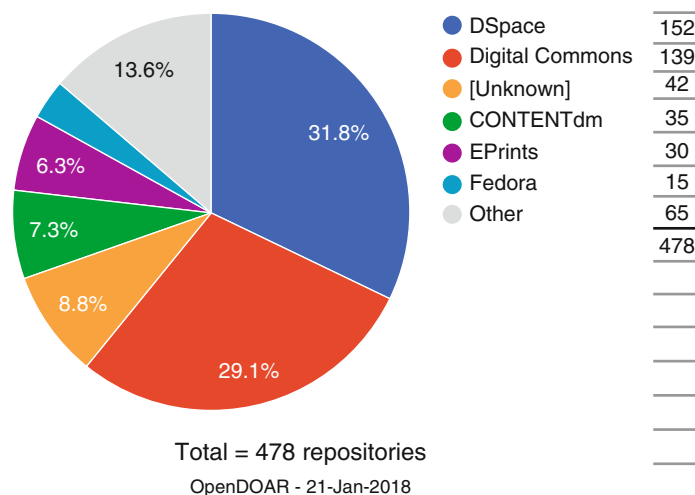
Challenges of Institutional Repositories

Many challenges have been identified in the literature confronting creation and management

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Fig 3 Common open-access software for IR.
(Source:)

Usage of Open Access Repository Software - North America, Institutional Repositories



of IR in academic institutions. Some of these challenges are identified and discussed as follows.

Policy Issues: For the IR to be effectively established, the committee in charge, in collaboration with the university administration, is expected to spearhead the enactment of OA policies. These policies shall be implemented in due course.

Required Equipment: The library in most institutions has realized the need for more computers and scanners. At the moment most of the units in universities use small scanner which is unsuitable for this kind of project. A high-connectivity scanner is needed to be ordered without further delay.

Staffing: Inadequate staffing has hampered the progress of most IR projects. There is to put an IR administrators in place in institutions to coordinate and manage the system and to assist end users with searching the repository. It is also important that a digitization specialist should be hired to serve as a knowledge expert for digital preservation issues and ICT staff for technical issues. So far these positions have not been created in most institutions. At the moment the electronic resources librarian manages the repository in most institutions while simultaneously managing

other units in the library. It is expected that the above information specialist should be involved with users based on the belief that relying totally on existing staff would be far too fragmented for the launch of this new service that needs concentrated attention. As the IR expands in scope, management, and support, resources will have to increase simultaneously.

Promotion: The adoption rate of the concept by the academics has been very low. The library must develop strategies to combat the challenge. Perhaps, as the library works with faculties who need to submit their content to an institutional repository, there is need to encourage them to retain copyright of their work or at least retain rights to publish their work electronically to increase the adoption rate.

Copyright Issues: The library plans to convince the management to mandate their funded researchers to deposit a copy of their articles in the IR. The library will consult with the legal officer to understand the institution's existing policies on copyright ownership for this is vital to the development and success of the repository. We also plan to offer presentations to academic staff and researchers on topics related to copyright and intellectual property rights in the digital age.

Full-Text Availability: Adding full-text availability needs to be addressed in the future. While much of this scholarship is available in full text through a library database, downloading these versions from a database might violate institutional licensing agreements with that vendor. When considering this, directly requesting full-text files from the authors themselves may be best, but even if they comply, many faculty members will still likely only send the publisher's final version, which may be most restricted in relation to IR use. A greater effort will need to be made to educate faculty members on why a preprint (manuscript) or postprint (post-refereeing) version of their work could be more easily added to the repository.

Limited Access: Venkadesan (2009) observed that limited access to scholarly publications is a problem. The author explained that the number of papers in the repositories should grow so that it can attract the users. Krishnamurthy (2008) identified that fund, legal framework, and technical concerns are the major barriers associated with the IRs. For example, the lack of source code for OSS used in IRs is a key challenge to the IRs. Cohen (2001) identified collection development, content organization, and online access to the printed output of researchers as challenges to the repositories. Cohen and Deborah (2007) identified problems such as platform selection, partnership with stockholders, and staffing requirements for creating institutional repositories and some other technical issues as barriers confronting IR. Similarly, Lynch (2003) added the budget crunches as another major barrier to the creation and management of the IRs.

Learning Object Repositories

Before defining learning object repositories, this entry first defines learning object. A learning object (LO) is any resource that can be used to facilitate learning and teaching that has been described using metadata. Learning objects are

self-standing, reusable, discrete pieces of content that meets an instructional objective. Learning objects may be tagged with metadata so that users can easily identify and locate specific learning objects in a web-based environment. The repositories that house such objects are known as learning object repositories (LORs). LORs are a recent technological innovation aimed at supporting, sharing, and reusing resources for teaching and learning (Margaryan et al. 2007). They are digital storage boxes that host collections of digital resources in a learning object format: i.e., resources that are designed to be integrated, aggregated, and sequenced in an efficient way to produce "units of learning" that are meaningful to learners. Resources in such repositories are collected on a personal, departmental, institutional, national, regional, or international basis (Margaryan et al. 2007). Libraries, organizations, or communities may have something about everything or everything about something, but having everything about everything is unlikely. Thus, a decentralized or "distributed" model of a learning object repository is a likely scenario (Griff et al. 2002). Instructional materials like policy guides, assignments, simulations, websites, tutorials, matrices, and other kinds of formats or media expressions are easier to find from within a contained collection.

Cebeci et al. (2008: 2) assert that "LORs play an important central role to achieve these goals with their search and retrieve components. With their metadata search(es) they facilitate the learners, teachers and developers to find appropriate objects that match their learning objective and the level of study." LORs make course selection easy and save time in helping users decide what courses are suitable for their learning purposes.

Learning object repositories offer users a large volume of resources that can be used in a number of learning scenarios and activities. This huge availability of learning materials can mislead or even hinder the users unless there is a well-thought-out guidance or assistance mechanism (Mayorga et al. 2006).

Matkin (2002) lists the characteristics of the ideal learning object repositories (LORs): These include:

Authoring/creating – Formation of a sound LOR should begin at the very beginning, i.e., at the creation of the learning object. Matkin explains that without the discipline of some minimal structure that contemplates its eventual storage and retrieval, the creative process may have a very small impact, no matter how well inspired.

Review and input control – Learning object repositories should establish standards for accepting learning objects. These standards should include peer review or some form of control over the quality of the learning object (Matkin 2002).

Intellectual property and digital rights management – LORs must address the intellectual property issues inherent in publishing material. The way intellectual property (IP) is addressed might range from a policy not to accept anything that has any property restrictions on it to a single, standard, and one-size-fits-all licensing agreement. Matkin gives example of the Connections Project at Rice University which provides contributors the choice of several licensing alternatives and restricts users according to the licensing arrangements they are willing to accept.

Modification, update, removal, and collaboration – The usefulness of LORs depends largely on how up-to-date and how easily the material within them can be modified (updated or improved) and removed. For many user communities, the ability to work collaboratively on the improvement of learning objects is important. This collaborative work requires sophisticated version control techniques and records. The essential dynamic quality of LORs is what sets them apart from content repositories, particularly those created and maintained by library professionals who are usually motivated by strong archival instincts. Matkin recommends that to be useful, obsolete or substandard material needs to be periodically removed from the repository, which means that the criteria for removal and the removal processes need to be established.

Retrieval systems – Elaborate retrieval systems for LORs have to be designed to make it easy

for users to find the elements of the repository they want. This usually means some form of authentication scheme to identify at least the user or the classification of the user and to bar access to users not qualified to use the LOR. Matkin emphasizes that good retrieval begins with a sound organization scheme for the data but also usually depends on sophisticated user interfaces designed to help the users understand the data organization and how their needs can be met. Creation of these interfaces requires knowledge of the motivation of the main body of users.

Technical infrastructure – LORs need an appropriate technical infrastructure. The hardware and software configuration, which includes elements establishing security for the system, telecommunication capabilities, continuous updates to the system, and appropriate operating and maintenance staff are essential, and they usually represent significant costs.

User information – The LOR should generate information about its users and how the materials within the LOR are being used. Gaining information about the use of the system is invaluable in understanding how the system should be changed or updated and how it should be marketed.

Community support functionality – If it is true that LORs are really serving communities of users, then LORs should provide some form of support to those communities. The ability of users to communicate with representatives of the LOR and with each other is highly desirable. However, directories of related resources, newsletters, and special web events might also serve user communities.

Scalability – Matkin (2002) argues that since learning object repositories are by their nature designed to grow, it is important that they be “scalable,” that is to say that they remain effective for higher and higher volumes of material in them, of users (including simultaneous users), and of transactions. The author indicates an important aspect of scalability is the effectiveness of the retrieval system to continue to deliver the right object to the user despite a proliferation of objects.

In summary, the attributes of institutional repositories (IRs) include the provision of critical component and the reformation of the systems for scholarly communication, serving as tangible indicators of university's quality, containing content deposited by owners, and managing, searching, controlling, and providing access to such content. Learning object repositories' attributes on the other hand include authoring and creating, review and imputing control, management of intellectual property and digital rights, modifying and updating control, removal, collaboration, and retrieval.

It is important now to state the specific benefits of both IRs and LORs to the communities they serve which include the university, repository managers, depositors, contributors, and end users. For the university, establishing an institutional repository enables a university to publicize its research and teaching programs by enabling access to the work of its staff and students. The academic work of an institution can be presented in one place rather than being just spread among hundreds of journals, thus increasing visibility and prestige. The quality of a university's academic output forms an effective advertisement for the institution, attracting external revenue streams, new faculty, and students. Deposit in a university repository can ease (for the institution and for the academic author) the administrative burden of reporting publications for research assessment and review exercises.

For the libraries, while some faculty members currently dedicate considerable time and energy to the technical aspects of delivering scholarly information, the faculty's primary role will remain as information contributors, end users, and change agents. In the long term, organizing and maintaining digital content as well as supporting faculty as information contributors and end users should remain the responsibility of the library. Libraries are best-suited to provide much of the document preparation expertise (document format control, archival standards, etc.) to help authors contribute their research to the institution's repository. Similarly, libraries can most effectively provide much of the expertise in terms of metadata tagging, authority controls,

and any other content management requirements that increase access to, and the usability of, the data itself.

To the depositor, contributors, and end users of IRs, research papers that are freely available online are on average downloaded and cited earlier and more often than those that are not. Depositing academic work in an open-access repository therefore increases the profile of an author on a worldwide basis, increasing both the dissemination and the impact of the research they undertake. Regular submission of authors' work to a repository provides authors with a central archive of their work and a record of publications to add to their CVs.

The benefits of LORs to the university presuppose that by managing its learning resources collectively, the university gains all the benefits and savings of scale, realizes the full value of learning assets and sharing and reuse of learning material, saves time and effort, and helps in building a common resource making it easy to identify new opportunities. To the individual on the other hand, it allows all participants in the learning process to have something to gain. Educators share a common store of learning resources, but can create and deliver them however they choose. The quality of teaching and training is improved because everyone has easy access to the best resources and support staff are aware that resources are securely stored and centrally managed.

Differences Between Institutional Repositories and Learning Object Repositories

There have been many writings on institutional repositories and learning object repositories, but few of them discuss or point out the differences between the two. This section considers this very important issue, which many authors have ignored. A learning object repository (LOR) is a collection of LOs having detailed information (metadata) about them that is accessible via a network or the Internet. In addition to housing LOs, repositories can store "locations" for objects

that are held elsewhere (The JORUM 2005: 11). This definition presupposes the ability to store “locations” for objects that are held elsewhere. This widens the range of the LOR’s content to include material stored on distributed servers almost anywhere on the Internet. The LOR is simply a database of LOs viewed as a warehouse of learning materials. The institutional repository (IR), on the other hand, is a concept that captures and makes available as much of the research output of an institution (e.g., a university) as possible. In the first instance, this might include material such as research papers and electronic versions of documents such as theses but may also include many of the digital assets generated by normal campus life, such as administrative documents, course notes, or learning objects.

Institutional repositories typically do not do versioning and do not support complex or many author workflows, but they excel in preservation strategies (e.g., DSpace) and media independence and are championed by libraries. Learning object repositories on the other hand do not archive in the real sense but have special capabilities to handle formats for learning resources (e.g., IMS, SCORM) that some others do not typically integrate well and also provide support for multiauthor workflows and versioning distinct from archiving.

Leslie (2004) questions the difference between institutional repository software such as DSpace and FEDORA and “learning object repository” specialized software such as CAREO and notes that DSpace’s FAQ page promotes the software as being multipurpose and cross-functional.

Institutional repositories can also be differentiated from learning object repositories in term of their purpose. While the primary purpose of an institutional repository has generally been said to store, preserve, and showcase to the world the intellectual output of the university, the primary purpose of learning object repositories is to facilitate sharing and reuse of resources across disciplines within a university or college or across higher or further education sectors regionally, nationally, or internationally.

In the issue about whether general institutional repositories such as EPrints, DSpace, Fez, etc. could take on the functions of a bespoke learning object repository (e.g., Intralibrary), it is also relevant to distinguish between the two repositories. An institutional repository is made to be adapted. This is to say that university should be able to change the schema and the services to adapt to local requirements, but contrarily, a learning object repository is just too different and specialized. For instance, the EdSpace project at Southampton is running learning resources repository based on EPrints, but they are experimenting with the nature of a learning object repository by introducing open-access practices and sensibilities rather than keeping learning behind institutional firewalls. They are building something interesting (which shows signs of being effective as well), but they certainly would not claim to be trying to replicate a learning object repository.

The audience for the two repositories differs. Academic publications in an institutional repository are intended to be read by other academic staff and researchers, and they can access them directly from the repository. However, learning materials in a learning object repository are intended for students. The materials will generally be delivered to students through a different online system such as the VLE or a web page. In some cases the tutor has to download the resource from the repository and then re-upload to the student system or post the URL to the resource. Students would not normally have access to the repository itself, just the resource.

The two repositories can also be differentiated in terms of IPR, reuse, and citation. For institutional repositories, tutors have a relatively clear understanding of copyright and IPR rules for scholarly work, and there is an agreed framework for citation and reuse of publications. In the case of learning materials in a learning object repository, many tutors are uncertain about IPR; they are unsure if they are allowed to repurpose a particular resource as there is no agreed framework for this.

The types of material housed by these two repositories are also different. Collections

of learning object repository materials arise in different ways. According to Rothery and Hayes (2008), some are created by individual teachers as their personal work. Some may be resource collections such as a collection of digitized photographs for a particular course, a collection of sound recordings for departmental use, a collection of students' work, or past examination papers. The authors add that some resources may have been purchased by the institution commercially, while other materials may be the output of a curriculum development project. They conclude that there is considerable variety in the source of the material, its ownership, how it is used, and its format. On the other hand, scholarly publications in the institutional repository are of a more consistent type and format.

Another antecedent to differentiate between the two repositories is the issue of retention. There is a tradition of preservation and archiving of academic publications in institutional repository, whereas there is little awareness of any need to retain and archive teaching materials in a learning object repository.

The peer review issue is another difference worth mentioning when differentiating between an institutional repository and a learning object repository. Scholarly works in IR are often subject to peer review or quality assessment prior to publication. This is not the case with learning resources in the LOR. Rothery and Hayes (2008) point out that it is indeed a matter of controversy how one might assess the quality, as learning resources can be used in many different ways, and its value is very much dependent on how it is used. Authors would probably welcome feedback from other teachers, though this is a different form of feedback from that which is obtained from an editorial board on a research journal.

Similarities

Both institutional repositories and learning object repositories (Knowles and Bailey 2007) "relate to the management of information; are primarily concerned with internal information; require a

combination of technology, policies, procedures & user behaviour; rely on the participation and engagement of the user; involve resource discovery; impose centrally-determined controls around the behaviour of information; may require access to digital content in the medium-long term (T)he kind of things being stored in them are the same, there is volatility in those things, and the relationship between authors and those things is one on one or one to many."

Both systems ostensibly provide a searchable archive for digital materials from an institution. Not only are the materials typically different (e.g., scholarly research papers versus teaching-focused content and applications; PDF files versus zipped SCORM objects, Java applets, etc.), but "digital repositories," with their heritage in the library and archives world, typically support different metadata schemas and are focused on interoperating with different kinds of systems (library catalogues instead of, say, course management systems), and this embodies a different business logic (Leslie 2004).

Lynch and Lippincott (2005) reveal in their study that the kind of materials that are in repositories today and the kinds of materials that are planned for inclusion in the near future are not only e-prints and electronic theses and dissertations but digitized special collections material, multimedia, course material, and datasets.

Repositories hold different types of materials in their collections, and yet these materials are managed in the same way. Repository collections are there to give users access to digital versions of journal articles, conference papers, book chapters, unpublished papers, etc., directly via the repository interface (or portal/computer screen). As a rule, users do not need special accounts but can access the repository collection from home via Google.

Regardless of whether the scope of the repository is broad, and the institution uses a common software base for all types of digital collections, or an integrated approach linking separate platforms is taken, there appears to be a correlation between the implementation of learning object repository projects and an institutional repository.

Guiding Policy of Repositories and the Likely Content of the Policy

When establishing repositories, there are varieties of decisions to make. Policies, systems architecture, and other elements will depend on institutional context and the scope and purposes of the repository. Policies appropriate for an academic institution may not work in a corporate setting. Not-for-profit organizations have unique purposes and cultures that will dictate how their repositories are formed and maintained. In the light of this, the guiding policy and likely content of institutional repositories should include the following:

1. The institution should build and maintain a repository to provide a permanent record of the intellectual output of the university and maximize the visibility, usage, and impact of this through open access.
2. Repositories should operate as a non-profit, non-commercial, open-access, institution-wide repositories with the aims of preserving and disseminating the scholarly output and other selected outputs of the institution (university/college/research institution).
3. Repositories should contain approved collections and sub-collections that encompass the corporate, research, and learning and teaching activities of the university.
4. The university/college/research institution will normally expect staff members engaged in scholarly activity to deposit the resultant research and publishing outputs within the repository. These may take the form of preprints (subject to appropriate quality control measures), postprints, project reports, audit reports, published materials, etc.
5. Repositories should always contain the resources that the university regulations require to be deposited.
6. Libraries and learning resources should manage and develop repositories on behalf of the university.
7. All materials contained within the repository should comply with copyright legislation and, where appropriate, publishers' copyright policies.
8. All materials should normally be retained indefinitely.
9. Whenever possible, materials should always be made available on an open-access basis.
10. The metadata associated with the materials deposited in repository may be accessed free of charge, but it must not be reused in any medium for commercial purposes without formal permission.
11. Institutions should endeavor to ensure continued readability and accessibility of all items deposited in repository.

Challenges of Institutional and Learning Object Repositories

As pointed out earlier, repositories whether institutional repositories or learning object repositories are beneficial in many respects. However, there are a number of problems and challenges faced by institution implementing them. This section is dedicated to the discussion of this subject.

Van Earwage (2008) asserts that there are many challenges facing library and other staff who manage an institutional repository. One of the main challenges is faculty participation. Without the willingness of the faculty to contribute their works to the repositories, the collection cannot be sustained for growth. There are many reasons why the faculty may be reluctant to participate in a repository. Some of these reasons include fear of backlash from a publisher and a belief that depositing their work is too time-consuming or holds little value.

Additionally, some faculty members are weary of providing content to a system that contains gray literature that has not gone through the process of being peer-reviewed. There is the concern that the existence of student created content will in some way detract from efficacy their own professional research or writings. To combat a lackluster community requires much advocacy and education as well as the building of strong library-faculty relationships. The faculty must learn to trust the library staff in order to feel confident in contributing to the IR.

Another challenge is maintaining the balance between ease of deposit and the need for preservation. The costs and risks associated with digital preservation tend to grow when a digital collection includes a large number of diverse file formats, as was found in a study commissioned by JISC (James et al. 2003). It seems good practice to prescribe the file formats accepted by a repository and limit the number to a few that are based on open standards. However, this consideration should not become a barrier that prevents authors from depositing content into the repository. For the convenience of authors, most repositories will probably accept formats other than those that are preferred but will perform format migration for archival and preservation purposes.

It should be stressed that it is not possible or perhaps desirable to keep everything that has been created. Digital preservation involves selection and appraisal, which are criteria and processes for identifying information for long-term retention and preservation. Selection and appraisal are interactive decision-making points within the lifecycle of a digital object connected to its active use and can be applied to help ensure institutional resources which are devoted to the long-term availability of the most valuable digital assets. Guidance on good records management practices and how appraisal can be done within the context of institutional repositories, for different types of content, is needed to help decision-making and answer the questions “what to keep?” and “how long to keep?”

There are also a number of challenges that affect both the structure/architecture of a repository and its content. These include those listed under:

Structure and Standards

The design of a repository needs to address the distinction between “archival resources,” i.e., those that are likely to be of long-term value, and “non-permanent” or transitory, i.e., those that have a very short lifecycle. Another challenge is to design a repository structure that not only

accommodates both structured and unstructured objects but also provides a mechanism for potential sharing of both types.

Culture, Politics, and Practice

Sullivan (2004) emphasizes that those involved in institutional repository projects have reported that the effort and organizational costs required to address repository policy, content management, and promotion to academic staff dwarf the technical implementation effort.

Based on collective understanding of the problems associated with learning object repositories (LORs), Matkin (2002) identified several domains which contain significant barriers to the creation, maintenance, and implementation of effective LORs. These are summarized as standards, technology, pedagogy, culture, intellectual property, organizational development, business models, and policy. Matkin (2002) concludes that there are two other aspects underlying these domains of LORs that need to be considered. These are scale and convergence. Matkin explains that there are clearly scalability issues in the developing of LORs. Very large-scale LORs will need to operate very differently from small-scale LORs, particularly if the creation and maintenance of a community of users are important. In addition, there is a strong impulse to build repositories that can ultimately be combined, either actually or virtually. While the standards movement theoretically serves this impulse, differences in attributes not covered by the standards are significant potential barriers to combination.

Other challenges could include the impossibility of interchanging objects because of inconsistency in size and language, lack of consistent classification schemes, and variation in quality despite the attempts to institute peer review or quality criteria.

Projecting into the Future of IR

As put forward by Otando (2010), future plans in terms of raising awareness at the university, the

library plans to come up with strategies to sensitize all staff and to present the project to the university community before the launch. The strategies include:

- Organizing workshops and training and visiting colleges and departments to sensitize academic staff and researchers on the need for submission of their research into the IR.
- Using posters, presentations, brochures, university magazines, library newsletters, and UoN and library websites to publicize the service.
- Identifying “champions” in academic departments who can encourage their colleagues to take part is often the most valuable approach.
- Taking up the opportunities of school/college academic board meetings to publicize the service.
- Writing a press release announcing the launch.

By projecting into the future of institutional repositories in most of our higher educational institutions, an inside-in/outside-out model has been recommended by Lorcan Dempsey, Vice President of Membership and Research and the Chief Strategist at OCLC (see Fig. 4).

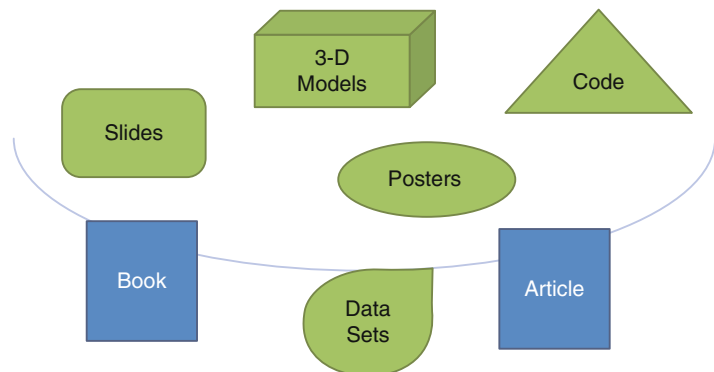
The “outside in” as explained by Lorcan Dempsey is the traditional role of libraries in acquiring external content for an internal audience, and “inside out” is the development of internal collections (archives, special collections, IRs) that are shared with an external audience. This framework is useful in understanding the growth of unique local and digital collections that have

different requirements in terms of staffing, systems, and the inherent and practical value to the institution. The books and journals that libraries acquire are a small portion of the digital content created by the academic community in the course of scholarship and learning. A much larger body of content in a growing variety of digital formats represents the output of the academic community and broader presentation of the dimensions of the scholarly information network. Scholarly communication is not limited to formal publishing. There are an expanding number of outputs in different formats that researchers need to access as part of the scholarly record. The IR writ large can house many of these formats, while others will be collectively addressed in disciplinary repositories.

However, a big question that comes to mind is the issue of sustainability. How will all the so-called IR created by our higher educational institutions be sustained? There is no doubt about the fact that library will continue to be relevant in terms of the management and maintenance of IR and more roles will continue to be created for libraries. Libraries therefore should endeavor to borrow leaves from the best practices around the world. For instance, Luther (2018: 14) explained that, “as the library’s role continues to evolve, some institutions, such as the University of Minnesota, have been able to analyze data that correlates student library activity with institutional metrics such as graduation rates, time to graduate, and returning students. Collaborating with other departments such as institutional research and IT to achieve joint objectives

Institutional Repositories Versus Learning Object Repositories, Challenges and the Way Forward for Higher Educational Institutions,

Fig. 4 Outside-in and inside-out model of scholarly communication in IR. (Source: Luther 2018)



also raises the profile of the library within the university and aligns it with specific goals of the institution.”

Luther (2018) emphasized further that anecdotes can be powerful tools for demonstrating the value of the IR since metrics often function as internal measures of platform performance for the library. Two examples of stories illustrate the role of the IR and its importance to other departments on campus. The Admissions Department at Illinois Wesleyan was enthusiastic about sharing student projects in the IR with prospective students and their parents to show the type of work being done at the university. Librarians at Utah State University gathered work from student-led interdisciplinary research groups in the sciences that highlighted the work of these communities, gaining greater attention for these programs beyond the university and leading to external funding for two projects.

To ensure that the IR is embedded in the university's information systems and services, the library in an institution should plan to develop an IR budget. The library should be in the process of soliciting for funds to buy facilities that can be used to establish the IR. Other future plans should involve enhancing staffing and skills, collaborating with other institutions to share technical skills, increasing collections in the repository, and providing access via the wide area network (WAN).

Conclusion and the Way Forward

This entry has examined institutional repositories and learning object repositories based on the argument that this area of research is being ignored by researcher over the years. Part of the key arguments to differentiate the two repositories centers on their definition, purpose, material and content housed, retention, audience, peer review process, etc. Argument about their similarities, on the other hand, relates to the fact that both institutional repositories and learning object repositories (Knowles and Bailey 2007) “relate to the management of information; are primarily concerned with internal information;

require a combination of technology, policies, procedures and user behaviour, etc.” It could be pointed out therefore that the key to a successful repository strategy will lie in the ability of repositories to share information and exchange records about learning objects and their provision of access to the objects themselves. In the light of this, the following are put forward as the way forward for higher education implementing these repositories:

Once prototypes have been developed for each of the starter projects, these will become pilot projects with academic staff involving faculty librarians, educational designers, and multimedia developers to test solutions and obtain feedback. The repository team should be keen to work with a school or center in managing their collection(s) of digital resources before rolling out the repository across all educational units.

Given the importance of resource discovery, it is anticipated that a new body should be organized to enhance access further. This body will continue to maintain close contact with institutional and learning object repository projects to share ideas and experiences. There is need for awareness of the benefits of ensuring there is interoperability across the higher education sector.

Universities and other tertiary educational institutions implementing repositories should continue striving to create a resource-rich, integrated learning environment that can be fully exploited by both students and faculty. A digital repository provides a flexible and discipline-independent mechanism for storing and managing digital objects, thereby enhancing integrating learning environments. In addition, university decision-makers should pay attention to maintenance issues.

Institutions implementing repositories should forget about their culture as this usually go a long way to serve as an obstacle on most occasions. Institutions should ensure careful selection of a core metadata scheme. This is to give room for consistency among the repository's initiatives. There should be consistency in the classification schemes, object, and size across institutional repositories. Issues relating to cataloguing of objects, retrieval of objects, organization and

archive, authorship, copyright, and language of the object will need to be resolved. There should be no variation in quality. Institutions should embark on or follow the same or similar peer review or quality criteria.

Moreover, there should be a common framework such as SCORM compliant for LOR in terms of technical issues. This typically consists of four components: (1) learning management system for managing the user and tracking progress through the content; (2) assets, specific web media such as HTML files, images, or video; (3) shareable content object for collection of assets that form a learning activity; and (4) content aggregation, an overall library of related content and shareable content objects. This idea is to promote integration of online learning products with learning management system (LMS) software.

Cross-References

- [Creative Commons](#)
- [E-Portfolio in Higher Education](#)

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Instruction

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- Support for School and Institutional Improvement and Accountability

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- Implementation of ICT in Secondary Schools

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-

Intellectual Property

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Intelligent Tutoring Systems

- [Artificial Intelligence in Education](#)
 - [Technology-Enhanced Learning in Programming Courses, Role of](#)
-

Interactive Displays, Use of Interactive Charts and Dashboards in Education

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Synonyms

[Interactive graphs](#); [Interactive images](#); [Interactive reports](#)

Introduction

Interactive displays are digital artifacts that comprise one or more interactive reports (charts, tables, or summary measures). The main component of such displays are interactive charts.

Interactive Charts

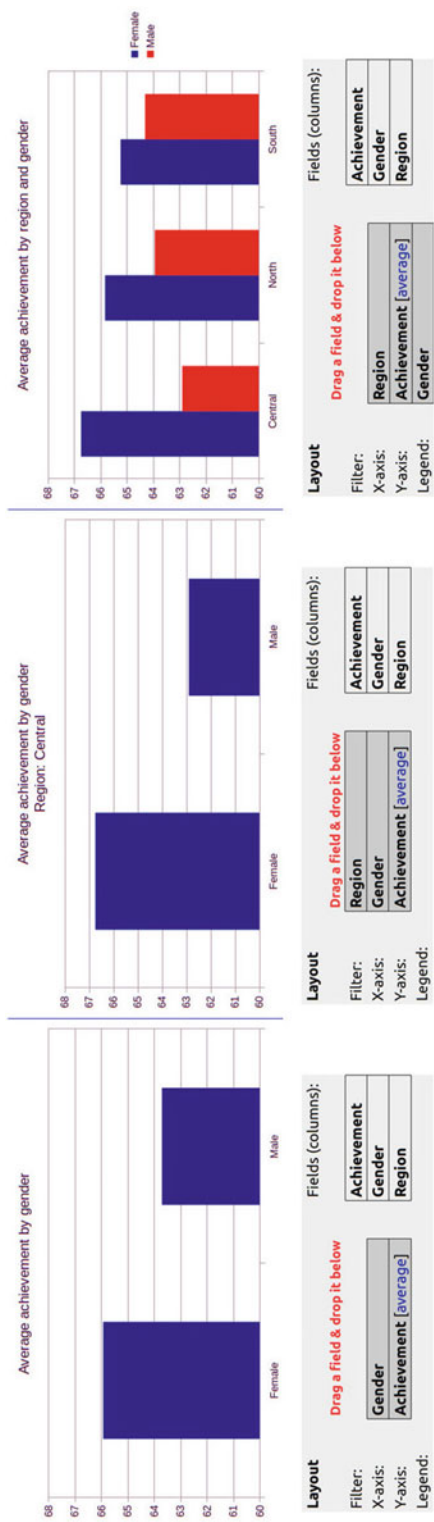
Interactive charts are descriptive, exploratory graphical displays, whose content updates automatically whenever changes in data or variables

considered occur. These changes may be the result of data update (done by software or a person working with these charts or preparing data to be used by them), or actions done by the designer/user of these charts, regarding the selection of a particular variable value, examination of one variable instead of another, or the addition of a new variable to the set of variables being considered.

Interactive charts, which can be (relatively effortlessly) used to visualize regularities and trends in data (if any), are typically built in a drag-and-drop fashion within a digital tool or environment. As a rule, simple mathematical models lie behind the visualizations produced (e.g., frequencies, sums, and means), and these models are, after the designer's selection, automatically applied by the tool used.

Consider, for example, students' achievement in one school subject at a state examination. An educator may first consider this achievement by gender, by creating and using an interactive chart that displays the average achievements for boys and girls, signaling some pattern (with *achievement* as dependent, y-axis placed variable, and *gender* as independent, x-axis placed variable; Fig. 1 left). The educator may then examine whether this pattern holds true for a particular state region, by upgrading the design of this chart to summarize only data regarding that region (with *region* as filter variable; Fig. 1 center). Finally, the educator may examine whether the pattern is stable or changes from region to region, by finally enhancing this design to display the achievement in each region by gender (with *region* as an independent, x-axis placed variable, and the values of *gender* used as legend; Fig. 1 right).

Apart from traditionally used charts (e.g., pie charts, bar charts, line charts; see Figs. 1 and 2), other less common chart types may also be applied, such as area, bubble, and map charts. Such types may, for example, be found at <https://ncva.itn.liu.se/explorer/> and <http://app.rawgraphs.io/>. All interactive charts may be viewed as technology-supported images, no longer representing (complex) information as mere static figures but rather as dynamic, interactive objects.



Interactive Displays, Use of Interactive Charts and Dashboards in Education, Fig. 1 Chart (above) and its underlying design (below): from achievement by gender (left) via achievement by gender for one region (center) to achievement by region and gender (right)

Dashboards

Interactive charts are used as building blocks of dashboards, which are, in brief, sets of two or more interactive reports. These reports are mainly charts, but summary measures (and sometimes tables) may also be used (see Fig. 2). Dashboards are usually built in a drag-and-drop fashion like the interactive reports of which they comprise. Designing a dashboard, environment (dashboards builder) may thus only require its user to drag-and-drop some individual, previously created interactive reports onto a dashboard canvas (any of available built-in canvas or a user-designed one). There is often a possibility to add a filter to the dashboard to enable slicing of the data considered (e.g., to examine learning errors for all students together or individually for groups of students categorized by their gender or study program).

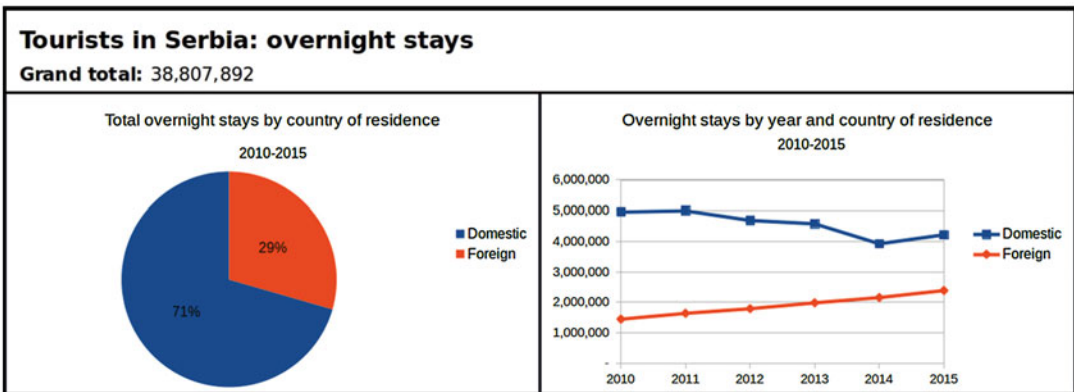
Initially created for the business world to display values of key performance indicators and signal when these values and their trends are good, acceptable or bad, dashboards have entered various industries, such as finance, transportation, healthcare, and sports (Wexler et al. 2017). They are becoming more and more common in the publishing industry (e.g., www.bookmetrix.com) and research evaluation (e.g., www.researchgate.net). A gallery of dashboards regarding various industries and areas can be found at <https://www.idashboards.com/dashboard-examples/>, for example.

What dashboards summarize in all these industries and areas are some performance indicators relating to various subjects and objects (e.g., assets, vehicles, patients, publications).

Educational Importance

It is no surprise that interactive displays, especially dashboards, have also entered education. They have been not only used to visualize learning outcomes (so-called learning analytics) but also to support work with data in various school subjects or university courses. Regarding such arranged work, if practiced within a suitable learning cycle (e.g., a mathematical modeling cycle), the work can support the understanding of this cycle and the realization of its values in capturing main features of disciplinary thinking, enabling also the development of important disciplinary notions (e.g., variable and functional dependence).

It is expected that many students will work with data as a foundation for their claims and actions regarding various professional issues. Such data usage, along with uncertainty, is central to STEM (science, technology, engineering, and mathematics) education (English 2016). As a result, there has been a noticeable demand recently for the inclusion of data science (i.e., the science of obtaining useful information from data by using various methods and tools) in



Interactive Displays, Use of Interactive Charts and Dashboards in Education, Fig. 2 Dashboard with two interactive charts and one summary measure: although not

dominant, overnight stays by foreigners are increasing (modified from Kadijevich 2016)

secondary education (e.g., Gould et al. 2017; <http://www.idssp.org/>), which may, at introductory levels, be realized using interactive displays.

Use of Interactive Displays in Education

Visualizing Learning Analytics

Dashboards are typically used to visualize learning data (Webb et al. 2018). With properly designed dashboards and suitable alerts complementing them (e.g., “Percent-correct score is below 40%!”), useful information about students’ learning (e.g., performance, engagement, interactions) can be provided to both students and teachers. A chart on a teacher dashboard may, for example, show that students who performed above average used various feedbacks (e.g., peer feedback, error correction feedback) more often than other students. Regarding a student dashboard, two charts may show that a student’s performance is below average and that his/her use of resources to aid learning is minimal. Various student and teacher dashboards are provided by the Graasp platform (<https://golab.graasp.eu>), for example.

Despite the promise of dashboards to improve learning and teaching, there is a limited knowledge of when, under what conditions, and to what extent the use of dashboards may improve them (e.g., Webb et al. 2018). Not only is there slim empirical evidence that learning analytic tools (e.g., dashboards) are effective for teaching and learning, but also learning analytic and its tools have also rarely been embedded in learning theories (Schumacher and Ifenthaler 2018). If, for example, to foster self-regulated learning, customizable student dashboards are advocated, we need a solid knowledge not only of student’s design choices (e.g., what he/she can see, what others can see, what source(s) of alerts can be) and their learning grounds and benefits but also of ways to resolve tension between personal autonomy and learning equity, taking care about anonymity and privacy (Roberts et al. 2017).

Promoting Different Kinds of Reasoning

Being able to support the viewing (and modeling) multivariate phenomena in a less complex and

more dynamic way than the traditional, paper-and-pencil one, interactive displays can be suitable means to foster statistical reasoning, particularly statistical literacy (SL). Apart from traditional SL components (e.g., representing and interpreting data; finding patterns and trends in data), the use of these displays can foster the development of some novel SL components, such as the notions of effect size and interaction associated with the analysis of multivariate data (e.g., Ridgway et al. 2013; Kadijevich 2016). (A visualization that, on average, males score 5% higher than females shows an effect size, whereas a visualization that there are different achievement patterns for males and females due to technology use signals an interaction between gender and technology use.) Research evidenced that these notions could be grasped by many statistically naïve secondary students when they used interactive displays available at <https://www.dur.ac.uk/smart.centre/freeware/> (Ridgway et al. 2013). To cultivate various SL components, as part of statistical reasoning, the use of dashboards may be practiced within an appropriate learning (e.g., data science) cycle, whose steps (stages) may be ask questions, consider data, analyze data, and interpret data (Gould et al. 2017).

Although the term data modeling has primarily been used in statistics (to denote searching for a stochastic model of data considered) and computer science (to denote a process that describes the content of a database), it has also been used to denote the work with data aiming at representing and interpreting data. To empower such data modeling (based on designing and applying multiple representations), interactive displays may be used. Sharing many common underlying skills with mathematical modeling, this kind of data modeling can be viewed as an instance of mathematical modeling. If aimed at prescriptive modeling (i.e., to recommend well-grounded changes of the world modeled), data modeling (or modeling with data) may follow a learning cycle that comprises six key activities (stages) – asking questions, preparing data, visualizing data, answering questions, validating modeling, and recommending changes (Kadijevich 2018). The application of this cycle would not only promote main features of mathematical reasoning (with respect to

developing, solving, applying, and improving simple models) but also enable the development of important mathematical notions, such as variable (dependent vs. independent) and functional dependence (linear vs. nonlinear).

The stage of preparing data (that will be visualized using interactive displays), which is present in both above-mentioned learning cycles, calls for various (mostly computational) thinking skills, such as organizing, structuring, collecting, querying, transforming, and auditing data. This means that apart from statistical or mathematical thinking, computational thinking (CT) may also be cultivated. CT basically denotes thinking processes involved in problem-solving with computer by applying tools and techniques from computer sciences. Provided that a versatile computer environment is used, data practice using interactive displays would also promote CT strategies, such as decomposition as well as rapid prototyping, top-down, and bottom-up approaches (Kadijevich 2019). The design of the dashboard presented in Fig. 2 may be the result of decomposition, whereas the dashboards presented in Fig. 1 may be built in a rapid prototyping fashion (i.e., an iterative process through which we incrementally show what one display will look like). A top-down approach is applied when we go from a dashboard as a whole to its individual reports as parts, whereas a bottom-up approach is used when we start from some individual reports and combine them to create a dashboard (these approaches are often combined).

Conclusion

To empower data practice aiming at representing and interpreting data, we may use specific digital tools called interactive displays. Through their use, we can visualize various learning measures, hopefully improving learning process and its outcomes. However, it is not clear when, under what conditions, and to what extent the use of such displays can improve learning, which may be explored in future studies.

Through the use of interactive displays we can also promote important disciplinary notions (e.g., linear vs. nonlinear functional dependence). And, if their application is practiced within a suitable learning cycle (e.g., data science cycle), such application can support the understanding of this cycle and the realization of its values in capturing main features of disciplinary thinking (e.g., statistical reasoning). However, although mostly based upon simple mathematical and statistical models, the use of interactive displays can generate a number of challenges (e.g., what measures to use; what charts to apply; what variables to use as legend and filter). Furthermore, various challenges may also be generated by the software used for developing these displays (e.g., how to build displays of increased structural complexity). These challenges may be better understood and pedagogically addressed if examined within a learning cycle with respect to its steps (stages) and transitions between them (Kadijevich 2018). Because our knowledge about the challenges and pedagogical ways of addressing them is scarce, further research may examine these issues in detail.

To foster self-regulated teaching or learning based on learning analytics, customizable interactive displays may be used, which would call for research studies focusing on design issues of such displays and their educational values. When the displays are used to promote disciplinary reasoning, these design issues may include some intelligent support, regarding, for example, assessing data quality, connecting simple and complex displays, and signaling possible data regularities in displays produced.

Cross-References

- [Computational Thinking](#)
- [Computers in Secondary Schools](#)
- [Educational Assessment, Educational Data Mining, and Learning Analytics](#)
- [Mathematics Education and Technology](#)
- [Science Education and Technology](#)
- [Technology Enhanced Learning](#)

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Interactive Graphs

- [Interactive Displays, Use of Interactive Charts and Dashboards in Education](#)

Interactive Images

- [Interactive Displays, Use of Interactive Charts and Dashboards in Education](#)

Interactive Reports

- [Interactive Displays, Use of Interactive Charts and Dashboards in Education](#)

Interactive Whiteboard

- [Information Technology and Assessment](#)

Interactive Whiteboards

- [Computer-Based Training and School ICT Adoption, A Sociocultural Perspective](#)

Intercultural Education in the Digital Age

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Synonyms

[Empathy education](#); [Multicultural education](#)

Introduction

Intercultural education and multicultural education are interchangeable terms that intend to educate people to appreciate living and knowing

diverse cultures, by learning with students from different backgrounds, nationalities, and cultures. Some writers suggest that there are differences between the two terms, but a recent study argued that they have many areas of overlap and that the different use of the terms is mainly caused by the fact that multiculturalism is the term widely used in the United States, whereas interculturalism is more frequently used in Europe (Holm and Zilliacus 2009). The entry considers the subject matter of intercultural education per se and the contribution of information and communication technology (ICT). It describes various policies and visions that promote learning about others and models of working collaboratively together. The focus will be on the digital area and how ICT contributes to the possibilities open to educators, policy makers, and practitioners to create innovative intercultural education. It will show a few examples that stress the value of ICT to increase opportunities for intercultural education.

In the digital era where globalization and migration are part of education, it is difficult to define cultures and determine how much it is related to nationality, religion, or identity. Culture includes traditions, heritage, language, religion, ancestry, aesthetics, thinking patterns, and social structures. As noted by the UNESCO (United Nations Educational, Scientific and Cultural Organization):

The current era of globalization, with its unprecedented acceleration and intensification in the global flows of capital, labor, and information, is having a homogenizing influence on local culture. While this phenomenon promotes the integration of societies and has provided millions of people with new opportunities, it may also bring with it a loss of uniqueness of local culture, which in turn can lead to loss of identity, exclusion and even conflict. This is especially true for traditional societies and communities, which are exposed to rapid 'modernization' based on models imported from outside and not adapted to their context. (UNESCO 2017)

The digital world could in one way destroy cultures but in another way can revitalize them (Resta et al. 2018). The Internet is creating a new culture and helping globalization to spread, but it also provides new opportunities where people can learn how to express their culture. The Internet

seems to decrease distance between cultures in one respect and increase cultural destruction on the other. In terms of languages, it might promote the dominance of one language, but on the other hand it raises the importance of language awareness (Finkbeiner and Knierin 2015). Therefore, knowledge and the acceptance for diverse cultures are much more important now than in the past.

Intercultural Education

There are four goals in education for an intercultural approach. The first is accepting the narrative of the other side and what this narrative implies as legitimate, without necessarily agreeing with the narrative. A second goal is to critically examine the contribution of the "my" side when there is conflict and what this entails, including the suffering of the other side. The third goal is to feel empathy for the other's suffering and to build mutual trust. The fourth goal involves an attempt to resolve conflicts in non-violent ways (Salomon 2000).

There are several stages in the ladder of goals for intercultural education. The first stage is a fatalistic acceptance of the presence of the other, as a solid given, unchangeable as a "necessary evil," sometimes out of hope or belief in the temporariness of the situation. The second stage is calculated, logical tolerance, which overpowers recoil or disgust of the other, usually out of a basic commitment to the values of humanism and political correctness. The third stage is the "anthropological" recognition of the other, out of curiosity and empathy, usually accompanied by a certain sense of superiority. The fourth stage is a sincere and genuine dialogue with the other, based on equality and mutual respect. The fifth stage is willingness for intercultural interaction between oneself and the other; and the sixth stage is a cultural merger, partial or complete (Tadmor 2003).

Wurzle (1988) presents a seven-stage model of education with an intercultural approach: the first stage, the beginning of monoculturalism; the second stage, the beginning of intercultural communication; the third stage, intercultural conflict, a

crisis that may arise as a result of intercultural contact; the fourth stage, educational intervention designed to heal the rift created during the conflict phase; the fifth stage, following the learning, the upsetting of the balance and confidence of the absoluteness of one's culture; the sixth stage, the formation of a new awareness toward oneself and toward the other; and the seventh stage, the integration of an intercultural perception.

In order to implement intercultural education, a structural change is needed which includes a change in the curriculum, learning materials, teaching and learning styles, perception and behavior of teachers and principals, and goals, norms, and culture of the school. In order to be able to bring about a significant change in the education system, intercultural education must be comprehensively implemented; this involves (1) integration of content, (2) building knowledge, (3) reducing prejudice, (4) egalitarian pedagogy, and (5) empowering the school's culture. In many countries those conditions are absent.

In a study conducted by Shapira (2008) in four schools with immigrant children, there was no trace of actual training to work in an intercultural system and about one-third of the staff members had attitudes that made it difficult to cope with the absorption of migrant children. Attitudes toward parents ranged from prejudicial to negative remarks toward the immigrants and attempts to bring them closer – often from a paternalistic perspective – and attempts to “educate” them. It seems that these attitudes are similar to those which were common in Israel in previous years.

Policies on Intercultural Education

Countries adopt a variety of approaches toward ethnic diversity in their societies: (1) assimilation, (2) liberalism, (3) regulation/division of power, and (4) intercultural policy. The first model – assimilation or the melting pot – tends to eliminate diversity in favor of a common denominator between the various groups that make up the society. The use of such a policy in the United States, for example, was aimed at immigrants who came from different parts of the world. Another

example is the melting pot in Israel in the 1950s, in which they tried to change the culture of immigrants, believing that only such a change would enable them to fully integrate into society. In this model, the state and its various organizations play a central role in the change processes which are designed to integrate newcomers or different ethnic/religious groups into society.

The liberal approach adopts cultural neutrality. The demands of the liberal state from its citizens amount to the acceptance of the basic democratic rules of the game, and the national identity, in this case, becomes essentially procedural (Habermas 1992, 2001). The ethnic-cultural identity, like religion in a secular state, reflects a preference, however important, that the state's citizens can express in their personal lives, but it is not really the state's business (Kymlicka 1995). It is the state's role to ensure equality among all its citizens and to prevent any form of discrimination derived from their cultural diversity.

Countries such as Canada and Australia have transformed their national definition into a multi-cultural identity designed to contain the different groups within them. The Australian government has adopted a national agenda for multiculturalism built on a three-tiered approach: the right to preserve cultural identities, the right to social justice and equality of opportunity, and the need to realize the economic potential and capabilities of all Australian citizens. Nonetheless, cultural diversity was limited by the insistence that the various groups comprising Australian society should be committed to the nation, to accept the basic principles of Australian society and to the recognition of the right of others to express their culture and worldly views. This fundamental statement was translated into symbolic representation of the various groups and their access to services and resources. In Canada too, where multiculturalism became an official policy in 1971, four main goals were formulated: supporting ethno-cultural groups' culture, helping these groups overcome obstacles of integration into society, encouraging meetings between various groups, and assisting immigrants in learning the official language of the state (Kymlicka 1995). At the heart of Canada's multicultural policy is the

assertion that all citizens have the right to preserve their culture and share it with others because their culture and language deserve to be preserved and strengthened with the assistance of state institutions and that all government institutions should adopt a policy that enables all the various groups to integrate into society and to encourage understanding and respect for diversity in Canadian society.

In African countries diversity is part of life since they are divided into different tribes. In Ethiopia, for example, the government officially adopted multicultural policies in 1991. Those were aimed at recognizing and allowing members of distinct groups within that society to celebrate and maintain their different cultural identities as a way to promote social cohesion. However, research done in schools calls for better implementation of multiculturalism (Solomon 2011).

In Britain, a committee was established, the Parekh Commission, whose main goal was to transform “multicultural emotions” into an informed process of structural changes in the patterns of action of the state and its various institutions. The committee summarized its vision as follows:

We believe it is possible and essential to create a society in which all citizens and communities feel valued, have equal opportunity to develop their skills and live a life full of content, receive a fair share of the collective responsibility and help create a community life characterized by a spirit of brotherhood, common identity and a sense of purpose that is compatible with the love of multiplicity and diversity. (Parekh 2000)

In Germany, diversity is a contested issue due to the government policy of accepting Turkish workers and in recent years, refugees from Africa and Muslim countries. The German government sees intercultural education as an important role for teachers to implement in schools. In addition to policies, they assert that diversity has a potential for getting to know others and their own culture. They support language awareness and stress that studying languages promotes intercultural competence (Kultusministerkonferenz 2013).

Shared education is the policy adopted in Northern Ireland to enable schools that are mainly

Protestant or Catholic in ethos to work more collaboratively together. After an initial phase of work, built around the notion that contact should be entirely face-to-face, Austin and Turner (2018) reported on work that started in 2017 when teachers were given professional development on how to use blended contact. No firm conclusions were reached about whether there was an agreed order in which to deploy the three elements of interaction, namely, asynchronous contact through a virtual learning environment, synchronous contact via software that offered real-time interaction audiovisually, or actual face-to-face contact.

Various countries have adopted a policy that can be described as multicultural, which has at the core recognition of group rights and adapting policies to the needs of ethnically diverse groups. But multiculturalism as a public policy provokes objections for the reasons mentioned earlier. Thus, for example, the declarations by British Prime Minister David Cameron and German Chancellor Angela Merkel that “multiculturalism has failed” bring back to the center of the debate not only the usefulness of the multicultural policy but also the alternatives to the democratic management of a heterogeneous state (Dobbernack 2010) and the rethinking of softened models of assimilation (Brubaker 2001).

ICT and Intercultural Education

In recent years, the use of online projects that offer collaborative learning in a multicultural environment and even between hostile cultures has been increasing. Information and communication technologies serve as a significant lever for learning, with affordances for various teaching and learning approaches. The digital environment enables the formation of heterogeneous groups that were not possible in the past due to physical limitations. Such an environment creates learning opportunities with students from different cultures and countries (Austin and Hunter 2013; Shonfeld 2017). It allows for the formation of relationships without the influence of stereotypes that may arise from external appearances (Shonfeld et al. 2013).

It can even contribute more successfully than a face-to-face intercultural meeting (Hasler and Amichai-Hamburger 2013).

In general, studies show that extended online contact between groups, in other words, without direct contact, may promote positive approaches among individuals who do not belong to the same group. Such contact may also promote tolerance toward foreigners, immigrants, and people without status and groups suffering from stigmas and reduce hostility between long-standing rival groups such as Catholics and Protestants in Ireland. Studies also show that intercultural interaction leads to greater willingness to seek real future contact among group members, including between majority and minority groups (Cameron et al. 2007). In specific cases, a change in prejudice as a result of digital contact was made in relation to Muslims and Christians in Australia (White and Abu-Rayya 2012) and Arabs and Jews in Israel (Walther et al. 2015).

Turner and Cameron (2016) underlined the potential value of blended contact in providing a means for young people to have much more frequent contact than would be possible through face-to-face work. Harwood et al. (2016) refer to the ways that online contact can overcome three of the challenges of face-to-face contact, namely, practicality, anxiety, and sustainability. These findings were confirmed by Austin et al. (2017) who demonstrated that ICT can supplement face-to-face work, notably by providing longer-term engagement between pupils than would otherwise be possible and offering teachers a model which is better able to fit into the demands of a busy teaching day.

Examples of Projects that Use ICT to Connect Cultures

TEC (Technology, Education, and Cultural Diversity)

The TEC model that was funded in Israel harnesses ICT to support intercultural education. It implements a gradual collaborative learning model based on advanced technologies for teachers, pre-service teachers, and pupils from

different ethnic groups and religions, yielding constructive dialogue and cooperation between diversified groups and eventually tolerance and mutual respect (Shonfeld et al. 2013).

The collaborative learning model of advanced Internet technologies is implemented within small teams from diverse cultures by the educators of the participating groups, progressing gradually from online communication (written, oral, video) to face-to-face interaction (Hoter et al. 2009). Through collaboration in joint assignments over a period of 1 year, team members get to know each other, develop mutual respect, eliminate stigmas, and reduce mutual prejudices. The in-service educators then implement the program in public schools and thus serve as major agents of social change, having influence on generations of students. Research has shown that the TEC model yields what have stated as “outstanding results” (Walther et al. 2015).

The TEC Center’s goal is to embed the model of online cooperative learning in the school system to change preconceptions, prejudices, negative opinions, and stereotypes that affect Arabs and Jews, and religious and secular Jews in Israel, from an early age. The program’s goal is to develop intercultural relations in cyberspace, connect young children in the school system, and start a discussion leading to understanding between the different cultures in Israel’s divided society.

The ABCs

The ABCs stand for autobiography, biography, and cross-cultural analysis which involves cultural self-analysis of differences and communication. It is a classroom model that develops cultural understanding and intercultural competence (Schmidt 2006). Its rationale is based on the idea that students, who write their biography, interview and write an autobiography of a colleague from a different culture and then carry out a cross-cultural analysis that will improve their communication skills as well as their intercultural competencies. This model moved to a digital platform, the intercultural exchange project, called ICE (the online intercultural exchange program).

CoGI

CoGI is a collaborative online program between students in Germany and Israel. It integrates the ABC's model with the TEC model. Students work online to create a product. However, they get to know each other and do the analysis when looking at similarities and differences between the different cultures (Finkbeiner et al. 2019). This project started in 2013 as a collaborative program between 2 instructors with 40 students and continued with more than 100 students and 5 instructors from different institutes.

Soliya

Soliya is a connect program that uses a digital platform. Its purpose is to empower young people to create connections within and between continents such as Asia, Europe, and North America. The starting point guiding the project is that of global citizenship – one that establishes awareness of the interdependence of individuals and systems – and the duty of responsibility derived from it. From this starting point, there is a need for continuous movement from individuals and communities toward a number of stages: improved intercultural communication, inclusive meetings within cultures, greater cultural awareness, and the realization of shared destiny and the need to find common solutions that will benefit all (Roberts et al. 2013).

The project is based on the development of dialogue which has five goals: (1) developing cross-border communication skills, which means the ability to be constructively involved in different environments in order to achieve a stable solution to common problems; (2) the development of empathy, which is the ability to build relationships and connect with other participants with respect and appreciation; (3) developing critical thinking; (4) promoting awareness, which means the ability to strive to understand and comprehend the basis of feelings, assumptions, values, and biases that shape different positions; and (5) activity. This includes the development of long-term interest in intercultural communication and involvement in opinions, in different cultures and values (Fournier-Sylvester 2016).

The Dissolving Boundaries Program

Following the Belfast Peace Agreement of 1998, the locally elected administration in Northern Ireland and its counterpart in Ireland set up the Dissolving Boundaries program which was funded from 1999 to 2016 and involved some 50,000 young people. Evidence has emerged from evaluation of this project that a blended approach has been welcomed by teachers. In the design of this work, the combination of the contact hypothesis (Allport 1954) and the reach of the Internet was found to be critical (Austin and Hunter 2013; Hasler and Amichai-Hamburger 2013). Moreover, recent research indicated that even a year after the contact came to an end, pupils displayed more interest and knowledge than matched pupils who had not been involved (Rickard et al. 2014). Their findings were confirmed by external inspection of the program (Education and Training Inspectorate, 2010/2011) and external evaluation (Bonnell et al. 2010). Key conclusions showed that pupils gained better understanding of each other and developed enhanced ICT skills. Teachers also gained extensive professional development through having to use ICT to plan joint work with teachers in another jurisdiction.

The E-Partners Program

Lessons learned from Dissolving Boundaries program use of blended contact, with schools that were some distance apart, were used in the development of the E-Partners program which ran from 2013 to 2015 and linked schools within Northern Ireland with the support of student mentors. Austin et al. (2015) reported that blended contact between two academic grammar schools had enabled teachers to appreciate the value of blended contact when faced with the demands of a crowded curriculum and examination pressures. A follow-up study the next year with 28 primary schools working in 14 cross-community partnerships found strong support for blended contact (Austin 2019).

Honey Bee Network: India

The Honey Bee Network comprises a comprehensive multimedia and multilingual database of

primary educational resources in native languages as well as information relating to innovations and ideas, including horticulture, biodiversity, and herbal medicine. In the same way that honeybees thrive on pollen from flowers, the Honey Bee Network is designed around the principle of information and knowledge sharing for the common good. By facilitating the cross-cultural and multi-linguistic exchange of ideas, the Honey Bee Network provides an opportunity to tap into the creative component of indigenous knowledge systems. The Honey Bee Network affords geographically disadvantaged peoples an opportunity to share their creations and ideas with their peers in other parts of the country and the global community (Honey Bee Network 2017).

TARASA

TARASA is a new initiative in Israel which enables everyone and everywhere to preserve and share any memory (text, photo, and video) without any preferences or cataloging. The very attractive and accessible website is based on the idea of relating all the memories to the relevant places and times on a global digital map (TARASA 2017).

The basic concepts of TARASA are that any memory which is meaningful to someone should be documented and preserved, that memories create a community, and that a social digital framework which brings together the memories of various communities can lead to curiosity, equitable reference, and mutual respect. TARASA creates a free space which is especially open to the memories and voices of excluded social sectors which have not been properly represented through dominant collective memories.

Discussion and Summary

The previous sections of this entry show that intercultural education is a moral imperative in a world which is experiencing both migration and population displacement on an unprecedented scale. Most young people are growing up in schools that are ethnically diverse and at a time when the reach of the Internet is making

both local and global communication via the Internet inexpensive and accessible (UNESCO 2011).

To address the challenges of developing social cohesion, online interaction and blended contact have been shown to make lasting differences to students' perceptions of each other (Rickard et al. 2014). In addition to political will at government level, teachers need professional learning to embed this kind of work in their daily working lives. That learning needs to be built around the principle that ICT communication software is not so specialized that only teachers who are technology experts can make use of it. It needs to be designed so that it is within the reach of any classroom teacher so that intercultural education can be developed through a wide range of different curricular topics.

In the broader context of the whole school, leaders need to develop a vision for their institutions that is both outward-looking and inclusive. Every child, irrespective of their ability or special needs, should be able to participate in classes which have an intercultural focus. Moreover, given that some of this work may challenge preconceived views of "the other," school leaders need to think carefully about how they include parents in intercultural education. Where schools have a strong connection to their local communities, parents can be drawn in naturally to intercultural programs, not least when their children use the Internet at home to extend the work they are doing in schools.

However, there would be little chance of this work becoming embedded in the curriculum without teachers and pupils having adequate access to an ICT infrastructure that provided high-quality Wi-Fi connectivity, hardware, and appropriate software. Different countries adopt a variety of approaches to this challenge.

There remain formidable challenges to this kind of work; examples abound where important projects simply grind to a halt when external funding and support is removed (Austin 2019). Farsighted politicians and administrators need to find ways to embed intercultural education in the curriculum and to be clear about what its outcomes should be.

In far too many parts of the world, the basic infrastructure is not yet in place on a regular basis to facilitate blended contact as a normal part of the curriculum. Even when it is, numerous papers note that ICT is being underused. For example, in Australia, Prestridge (2012) cites evidence that “only a minority [of learners] are reaping the benefits of the information technology revolution” and there are similar concerns expressed for Turkey (Goktas et al. 2008), Norway (Krumsvik 2014), the United States (Foulger et al. 2017), and Spain (Gil-Flores et al. 2017).

However, when we count the cost of not enabling young people to learn about each other, we can see the dangers that can arise from children learning in monocultural settings. Prejudice flourishes when the right kinds of contact with others are absent or limited. Stereotyping of others by class, ethnicity, or religion is often the start of a process which can lead to discrimination and conflict.

Evidence in this entry showed that the use of ICT, particularly as part of blended contact, can make a lasting impact on young people and their teachers (Austin and Hunter 2013; Walther et al. 2015). But it will require sustained political will both internationally and nationally to reap the considerable benefits of this work and ensure that it becomes the norm rather than the exception in schools.

Cross-References

- [Building Rural Renaissance and Suburban Development with Interactive Technology Solutions in India](#)
- [Collaboration and Social Networking](#)
- [Collaborative Learning and Patterns of Practice](#)
- [Distance Learning](#)
- [Teacher Education, Thinking About ICT](#)

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Interdisciplinary Science Teaching

► Science Education and Technology

International Olympiads in Informatics

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Synonyms

Computer science olympiad; Computing olympiad; Contest in informatics; IOI; Programming contest

Introduction

Recently in many countries educators and families have raised a question about what is the real effect of new smart technologies in the learning outcomes of the school education. Obviously, the smartphones and services provided by them are considered to pose a threat to the traditional teaching and learning. There are a lot of discussions in media about this topic. Following the trends, the educational authorities are producing new types of policy papers to tackle the issue. The computer play industry is flourishing, and consequently computer programming is becoming a more and more popular subject in the schools.

Although informatics is not taught as a discipline in many countries, school students are invited to participate in an informal training and different contests on informatics organized all over the world. Contests are exceptionally valuable for motivating and involving students in computer science (informatics). The current entry discusses the Olympiads in informatics arranged internationally and continuously. The main attention is paid to the model of International

Olympiad in Informatics, or IOI – abbreviation that computer science education community has used. But there is some discussion about the local and national contests. The relatively long history of the IOI proves that computer programming has a very strong attraction to school students making the IOI competition an intellectual fulfillment of the year.

The commonly used informal way to introduce informatics in education is to attend contests and Olympiads on programming. Contests make learning programming more attractive for students, help them to develop problem-solving and computational thinking skills. Social aspects increase motivation to communicate with other students, and during contests students meet their peers from all around the country or countries, make friends, and wait for the next competition ready to show that their abilities have improved since the last participation.

Petar S. Kenderov in his article “Three decades of international informatics competitions (How did IOI start?)” has studied the roots of the International Olympiad in Informatics (Kenderov 2017). The IOI was initiated in Bulgaria with support of the United Nations Educational, Scientific and Cultural Organization (UNESCO). In October 1987, the Bulgarian delegate Professor Blagovest Sendov proposed in the 24th General Conference of UNESCO in Paris the idea of initiating international Olympiads in informatics for school students.

After 2 years, UNESCO initiated and sponsored the first IOI which was conducted in Pravetz, Bulgaria, from 16th to 19th of May 1989. The Olympiad was modeled after the International Mathematical Olympiad (IMO 2018). For instance, the participating countries were required to send sample problems to local organizers in advance from which the International Jury had to select the problems to be given at the competition.

In the first IOI, 13 countries participated: Bulgaria, Cuba, Czechoslovakia, Federal Republic of Germany, German Democratic Republic, Greece, Hungary, People’s Republic of China, Poland, the Soviet Union, Vietnam, Yugoslavia, and Zimbabwe. Teams consisted of four students and two

team and deputy leaders; only the teams from Hungary and from Yugoslavia had two students each. Bulgaria participated with two teams and the Soviet Union with three teams. Thus, altogether, there were 46 students in 16 teams participating.

Only participants younger than 19 years old by the beginning of the competition were admitted. In the first half hour after the start of the competition, the participants had the right to put questions to the International Jury (in written form) concerning the formulation of the problems. The student work was preliminary checked and assessed by the respective team leader and then finally marked by the official coordinating commission. The final marking was with the International Jury which needed also to decide how many first, second, and third prizes are to be given to most successful participants.

The IOI is one of international science Olympiads designed for the four (with exception of IOI in 1995 when the Netherlands allowed five students in a team if at least one girl was chosen) best high (upper secondary) school students from each participating country selected through internal National Science Olympiads.

The IOI is organized annually in and by one of the participating countries. Each participating country typically sends a delegation of four contestants and two accompanying adults. Location and dates of the previous IOI are as follows:

Tsukuba, Japan, September 1–8, 2018
Tehran, Iran, July 28–August 4, 2017
Kazan, Russian Federation, August 12–19, 2016
Almaty, Kazakhstan, July 26–August 2, 2015
Taipei, Taiwan, July 13–20, 2014
Brisbane, Australia, July 6–13, 2013
Sirmione-Montichiari, Italy, September 23–30, 2012
Pattaya, Thailand, July 22–29, 2011
Waterloo, Ontario, Canada, August 14–21, 2010
Plovdiv, Bulgaria, August 8–15, 2009
Cairo, Egypt, August 16–23, 2008
Zagreb, Croatia, August 15–22, 2007
Mérida, Yucatán, Mexico, August 13–20, 2006
Nowy Sącz, Poland, August 18–25, 2005
Athens, Greece, September 11–18, 2004
Kenosha, Wisconsin, USA, August 16–23, 2003

Yongin, South Korea, August 18–25, 2002

Tampere, Finland, July 14–21, 2001

Beijing, China, September 23–30, 2000

Antalya-Belek, Turkey, October 9–16, 1999

Setúbal, Portugal, September 5–12, 1998

Cape Town, Republic of South Africa, November 30–December 7, 1997

Veszprém, Hungary, July 25–August 2, 1996

Eindhoven, the Netherlands, June 26–July 3, 1995

Haninge, Sweden, July 3–10, 1994

Mendoza, Argentina, October 16–25, 1993

Bonn, Germany, July 11–21, 1992

Athens, Greece, May 19–25, 1991

Minsk, Belarus, July 15–21, 1990

Pravetz, Bulgaria, May 16–19, 1989

The IOI host countries are usually selected from among the candidate countries 3 years ahead of the IOI in question. The selection is made in the International Committee of the IOI. In 2019 the IOI will be held in Baku, Azerbaijan, 2020 in Singapore, 2021 in Egypt, and 2022 in Indonesia. Each IOI organizing country has published a website of its own containing all official information, news, etc. In addition the IOI is maintaining an official website for general information about the IOI (2018).

Contests on Algorithms and Programming for School Education

To find jobs in the future, students also need to be able to have a deep insight in many issues like solving problems creatively, work in teams, communicate clearly in many media, learn ever-changing technologies, and categorize a flood of information. Developing abilities to master modern technologies and skills for solving problems is among the most important capabilities of an educated future citizen of the twenty-first century. Technology literacy and information literacy are one of the most important citizen's literacy skills. Today the emphasis is on deep thinking skills or understanding going beyond technology. Computational thinking is one of the most important future abilities which include abstraction,

analyses, data handling, pattern recognition, modeling, simulation, as well as problem-solving using algorithms and programming languages.

Programming, with emphasis on algorithms, remains the core of contests and competition and stimulates the learning process. Programming is an activity composed of several components: comprehension of the problem, choosing algorithm, encoding it, debugging, testing, and optimizing. Since many of the skills required for successful programming are similar to those required for effective problem-solving, computer programming and particularly choosing one of several possible solutions and later debugging in a short period of time provide a fertile field for developing and practicing problem-solving skills in an environment that is engaging for young students.

There have been many academic competitions and contests in computer science all over the world. Most of them are programming contests with focus on algorithmic problem-solving.

Two main paradigms for implementing contests are common over the world: from an international level to the local one (top-down strategy) and vice versa and from local activities to an international promotion (bottom-up strategy). The first paradigm is a challenge to find some suitable international contests, analyze, train students, and join them after intensive work. The second paradigm stresses an opportunity to establish the local contest and attempt to develop it to an international level. The IOI is a contest referred to the first competition paradigm, while the *Bebras* international challenge on informatics and computational thinking (Bebras 2018) belongs to the second paradigm. The main issue of contests is task; they should be interesting and systematically prepared, recognizable by computer science community, etc. (Dagiene et al. 2017). Finding interesting and adequate tasks that can be solved in a few minutes seems to be much more difficult in the field of informatics than in the field of mathematics.

Olympiad movements in many countries and regions can be considered as the most significant contribution of the IOI to computer science education. Only 13 countries participated in the first

IOI, whereas nowadays more than 80 countries are involved. Almost all these countries organize national local contests or Olympiads in informatics to train students as well as teachers. Some of these contests were implemented following the IOI model (with some adaptation to national peculiarities), although some countries are concentrated on their own infrastructure of contests. Additionally, there are regional Olympiads in informatics, e.g., African, Asian, Arabic, Balkan, Baltic, and Central European. Usually they are organized in the same manner as the IOI.

Structure of the International Olympiads in Informatics

According IOI Regulations (IOI 2016), the primary goal of the IOI is to stimulate interest in informatics (computing science or computing) and to bring the discipline of informatics to the attention of young people. Another important goal is to discover, encourage, bring together, challenge, and give recognition to young people who are exceptionally talented in the field of informatics and to have them share scientific and cultural experiences. Also, it is significant to foster friendly international relationships among computer scientists and informatics educators. One of the main objectives in each country is to discover, encourage, and train exceptionally talented young people in computer science.

Competition takes place during 2 competition days both of which are directly preceded and followed by a noncompetition day. The contestants are required to solve the competition tasks given to them, together with any translations and materials permitted by the competition procedures. Evaluation is to be carried out directly after the competition in accordance with the judging procedures.

A national delegation of a country is to be headed by a team leader and a deputy team leader. The maximum number of students is four. The delegation could also be observing: then it may include only a deputy leader but no contestants. The team leaders have the obligation to translate the tasks to a language which the students

understand. The leaders also have the responsibility to make sure that all members of the national delegation abide completely to the competition rules.

Guides have an important role in the IOI event. Traditionally every delegation has its own guide during the IOI week. The contestants usually need more guidance than leaders, guests, and other participants. The guides' duty is to introduce the environment to the delegation, for example, the venue, the hotel, the cafeteria, the city, etc. They make sure that everybody is in the right place at the right time. They attend the excursions and spend leisure time with the contestants.

A contestant is a student who was enrolled at a school for secondary education during the period September to December in the year before IOI. Contestants are not older than 20 years on the 1st of July of the year of IOI.

The students compete individually and try to maximize their score by solving a set of problems. The IOI contestants are required to express their algorithms in one of the allowed programming languages, currently Pascal, C/C++, and Java (Pascal will be removed from the list probably by 2019.). The contestants must engineer their programs to run flawlessly, because grading is based on automated execution.

Bodies and Committees

The IOI is managed by the General Assembly (GA), which is a temporary, short-term committee composed of the leaders of all the participating countries and by several long-standing committees. The International (Steering) Committee (IC) consists of representatives of the past, present, and future IOIs as well as several elected representatives. Its task is to retain the continuity of the IOI by finding future host countries. The second committee is the IOI Scientific Committee, the task of which is to ensure continuity and quality control of the IOI competitions.

The IC is a long-term standing committee. It consists of 11 voting members, all from different participating countries, plus a nonvoting secretary. The main task of the IC is to supervise the continuity of the IOI by finding future host countries, examining the organization of future IOIs,

solving problems encountered during the organization of an IOI, evaluating past IOIs, and adjusting the format and content of the IOI to ensure that the IOI goals will be met in the future.

The IOI international Scientific Committee (ISC) was established at the GA Meeting in 1999, at IOI'99 in Antalya-Belek, Turkey. The ISC consists of past, current, and future IOI host countries and members elected by the General Assembly. Totally, the ISC includes seven members. The task of the ISC is to guarantee the smooth operation of the IOI by meeting before each IOI to screen the problem set and test the grading system.

The International Technical Committee (ITC), a long-term standing committee, works with each host country to ensure continuity and quality control of the IOI competition environment (hardware and software). Members of the ITC may not be members of a national delegation. The ITC consists of seven voting members, all of them computer specialists with a background in Olympiad contest systems.

Ceremonies and Other Activities

At the opening and closing ceremonies, the speeches could be given. Usually they are speeches of thanks and summary of the IOI, and finally the host country hands over its responsibilities to the next host. The IFIP greeting belongs to the closing ceremony as well. Entertainment performances have also been very common.

The highlight of the closing ceremony is the awards ceremony. At the IOI the bronze medal is given to one quarter, silver medal for one sixth, and gold medal for one twelfth of all contestants.

The social and cultural program is an integral part of the IOI event. The organizer has an opportunity to show its creativity and make the IOI event memorable. The social and cultural program allows delegates to mix informally and network but also to experience something spectacular from the host country. The local convention bureau, conference offices, travel agencies, etc. are invaluable assistance in planning the social and cultural program.

The IOI program includes 2 leisure days with excursions. The excursions provide unforgettable

experiences for the participants. Nature usually offers many possibilities and every country has its own specialties. Culture has a great role in the social and cultural program. People usually want to experience the culture in one way or another.

Tasks and Evaluation

The purpose of the IOI tasks is to measure the skills of the students in writing effective and correct software code. The IOI tasks must meet several requirements before they can be accepted to be used in the IOI competition. The language must be standard English without any features which can be interpreted as a local expressions or dialects. The task texts cannot be too long because this might cause the student to give up solving the task even if the task itself could be simple. The tasks cannot be derived from any very specific area of the computer science. An important issue is that the tasks should be interesting enough to motivate the student to solve the given task. This also means that at least some part should be relatively easy and some parts relatively difficult. From the organizers' point of view, the task is failed if it produces a big number of zero points or a big number of full marks. Solving tasks should give a realistic evaluation to the students about their skills compared with other students.

The IOI tasks are of algorithmic nature; however, the contestants must show such basic information technology skills as problem analysis, design of algorithms and data structures, programming, and testing.

Tom Verhoeff, one of the leading persons in developing tasks for the IOI, wrote an article analyzing the IOI tasks of the first 20-year history; he summarized task type and difficulty level and classified them according to concepts involved in their problem and solution domain (Verhoeff 2009). Difficulty level is determined based on what percentage of contestants were able to "fully" (a submission should be scored 90% or more) solve the task.

The earliest IOI featured a single task on a single competition day. The next three IOIs each had 2 competition days with a single task, while at

IOI'93 there were three tasks on the first day and only one on the second day. The first 3 years, input-output (I/O) was through a console interface (keyboard and screen) and thereafter through disk files. Grading was done manually by an evaluator who operated the program on the contestant's computer.

At IOI'95, a new kind of task was introduced, referred to as reactive or interactive tasks, as opposed to the "classical" (single-) batch-style tasks. In a batch task, all input data is available at the beginning of the run, and it does not depend on the program's behavior. In a reactive task, some output must be produced before new input becomes available. That input may depend on the preceding output. The program has a dialogue with the (programmed) environment.

Another new type of task was introduced later. They became known as output-only tasks, where the contestants do not submit their programs but only the output files for several given (i.e., non-secret) input files. Of course, creation of the output files requires algorithmic thinking and in most cases also considerable amounts of programming.

Subtasks as a means of offering an opportunity for partial credit came into disuse in the second decennium of IOI.

Test run clustering was introduced at IOI 2005 to reduce the opportunity for harvesting undeserved points by guessing and other forms of opportunistic programming that is not aimed at solving the actual computational task. The points for a cluster of test runs are awarded only if all test runs in the cluster are successful. More generally, the score for a cluster is defined as the minimum of the scores for the constituent test runs.

The use of centralized *Linux* servers for grading was introduced in 2001. This allows better control over resources (time, memory, files, network) used by submitted programs during the evaluation test runs. The contestants submit their work through a web interface to the contest support system, where evaluation takes place.

Russian delegation leaders V. Kiryukhin and S. Okulov (2007) have published a book about all tasks of the first 18 IOIs, including the task descriptions, analyses, solution guidance,

classifications, and pseudo-code and Pascal implementations.

Many of the tasks are too hard to use “as is” in regular CS courses for secondary education. The kind of algorithms that nowadays plays a role at the IOI is too advanced for incorporation in the high school curriculum.

However, in international competitions, testing is the only way the solutions are evaluated. This is mainly due to the multilingual community and a huge amount of solutions to be evaluated in a short period of time.

Testing of batch-type problems involves creating a set of input data cases, running the program submitted by a contestant with those input cases, and then analyzing the obtained outputs. There are some principles used for creating tests. First, various solutions of different efficiencies are analyzed and programmed. Second, tests are generated or manually designed to reflect the efficiency of solutions and the correctness of boundary situations.

The programs submitted in IOIs are evaluated as black boxes. The contestants do not have an opportunity to submit their design ideas to be considered in the evaluation process. If they have a correct but inefficient program, they know it will not give them full marks (maybe 60%).

The programming languages that may be used in the IOI competition are now restricted to Pascal, C/C++, and Java. Pascal will be removed from the list probably by 2019. Python has been a promising candidate during more than 10 years and is still a strong candidate. The challenge in involving new languages in the competition is the amount of labor resources needed to upgrade the competition environment to adapt the new language.

The nature of previous tasks should not constrain the design of new tasks; the submission of novel task types not yet seen in IOIs is encouraged. We are particularly interested in tasks whose basic rules (if not optimal strategy) are accessible to a wide audience and tasks that illustrate algorithms and computational problems that arise in a variety of human endeavors. Open-ended tasks, ones that do not necessarily have a known efficient or optimal solution, are welcome.

Each competitor has her or his own workstation. There is no restriction on the number of times a program may be edited, compiled, and run on the workstation. The workstations have network access to the grading system, as well as facilities such as printing and solution submission.

Grading and evaluation take place on the grading system, which provides a similar execution environment to that of the contestant workstation. Grading workstation will have the same hardware and software configuration as contestant’s workstations (except for programs required for monitoring and grading system).

Nowadays there are a reasonable number of grading systems available for the competition. Sometimes the host country creates its own grading system, and sometimes the system from some earlier IOI is accepted.

The IOI Conference on Olympiads in Informatics

The IOI community consists of over 80 participating countries. We face mainly the same problems: how many of the countries have national Olympiads in informatics? Do they have some other contests on programming? How do we pick our students? How do we train them? The IOI presents an ideal forum for discussing these experiences and associated issues. It was decided to establish conferences during IOIs.

The idea to organize the conference during IOI, when students have solved their tasks, was raised at GA Meeting during IOI 2006. It was decided to send a call for papers, to publish proceedings (a journal *Olympiads in Informatics*), and to run the conference next year. The first IOI conference was held in Zagreb, Croatia, in 2007 during the first and second competition days. The 17 selected papers discussed the running of and issues facing several national Olympiads: Brazilian, Canadian, Chinese, Croatian, German, Italian, Polish, etc.

Next IOI conference was organized in Cairo, Egypt, and it concentrated on training and task types, and many of the ideas and experiences were drawn from the national Olympiads. Tasks are perennial issue for contests, their most visible

aspect, and, for many contestants, the primary reason for participation. The IOI community strives for quality, variety, and suitability. We endeavor to make tasks interesting, understandable, and accessible.

The IOI conferences are followed by the proceedings *Olympiads in Informatics* (2018). It is a refereed scholarly journal that provides an international forum for presenting research and development in teaching and learning informatics through competition. Submissions of papers are flexible, and there are no requirements to participate in the conference while paper is accepted. Now the journal *Olympiads in Informatics* is indexed by Scopus, Inspec, Eric, Era, and other databases.

In 2016, the IOI journal celebrated its 10th year anniversary. This year we have published two volumes, as we are delighted to publish a special volume celebrating the informatics education of our host, Russia Federation.

During the existence of the IOI journal, more than 200 papers were published showcasing 200 authors from 50 countries. Technical papers and country reports, views, and opinions.

Regional and National Olympiads in Informatics

The national Olympiads exist in a wider community – of course, it is also true for the international Olympiads. In order to ensure better preparation for the IOI and to strengthen regional relations, various regional Olympiads are organized. While the national Olympiads represent informatics teaching traditions of each country, the regional Olympiads are usually a mini model of the IOI, allowing the participants to experience what they will come through in the IOI.

The first *Balkan Olympiad in Informatics* (BOI) was for the first time organized in 1993 in Romania and every year thereafter.

Timisoara, Romania, July 7–13, 2018

Chisinau, Moldova, July 2–8, 2017

Nicosia, Cyprus, June 27–July 2, 2016

Ruse, Bulgaria, June 28–July 3, 2015

Ankara, Turkey, August 10–17, 2014

Sarajevo, Bosnia and Herzegovina, September 7–14, 2013

Belgrade, Serbia, August 15–19, 2012

Bistrica, Romania, July 3–9, 2011

Petrovac, Montenegro, September 18–25, 2010

Shumen, Bulgaria, November 27–29, 2009

Bitola, Macedonia, October 2–8, 2008

Chisinau, Moldova, July 7–13, 2007

Nicosia, Cyprus, October 20–25, 2006

Rhodes Island, Greece, September 3–8, 2005

Plovdiv, Bulgaria, July 3–9, 2004

Iasi, Romania, July 14–20, 2003

Belgrade, Serbia and Montenegro, June 21–26, 2002

Durres, Albania, September 8–13, 2001

Ohrid, Macedonia, May 15–19, 2000

Ioannina, Greece, August 22–27, 1999

Ankara, Turkey, July 13–19, 1998

Drama, Greece, September 30–October 5, 1997

Nicosia, Cyprus, October 19–25, 1996

Varna, Bulgaria, October 5–11, 1995

Thessaloniki, Greece, October 1–7, 1994

Constanta, Romania, May 24–29, 1993

The Central European Olympiad in Informatics (CEOI for short) inspired by the fast-growing popularity of the IOI, the Romanian team proposed in 1993 to organize a similar event for the Central European countries (as a matter of fact, they have been organizing the Olympiad in Informatics of the Balkan countries since many years). Shortly thereafter, Romania officially invited the teams of Austria, Croatia, the Czech Republic, Hungary, Poland, Slovakia, and Slovenia to participate in the first Central European Olympiad in Informatics. Five of these eight countries Croatia, the Czech Republic, Hungary, Poland, and Romania sent their teams to Cluj in May 1994 where, upon special invitation, four more teams from Moldavia, Romania, Yugoslavia, and Turkey took also part in the contest. CEOI'94 was hosted by the “Tiberiu Popovic” secondary school in informatics, Cluj; the organizing committees were headed by Ms. Clara Ionescu and Dr. Horia Georgescu (CEOI 2018).

Bratislava, Slovakia, July 23–29, 2019

Warsaw, Poland, July 12–18, 2018

Ljubljana, Slovenia, July 10–15, 2017

Piatra Neamț, Romania, July 18–23, 2016
Brno, Czechia, June 29–July 4, 2015
Jena, Germany, June 18–24, 2014
Primošten, Croatia, October 13–19, 2013
Tata, Hungary, July 7–13, 2012
Gdynia, Poland, July 7–12, 2011
Košice, Slovakia, July 12–19, 2010
Târgu Mureș, Romania, July 8–14, 2009
Dresden, Germany, July 6–12, 2008
Brno, Czechia, July 1–7, 2007
Vrsar, Croatia, July 1–8, 2006
Sárospatak, Hungary, July 28–August 5, 2005
Rzeszów, Poland, July 13–17, 2004
Münster, Germany, July 5–12, 2003
Košice, Slovakia, June 30–July 6, 2002
Zalaegerszeg, Hungary, August 10–17, 2001
Cluj-Napoca, Romania, August 24–31, 2000
Brno, Czechia, September 2–9, 1999
Zadar, Croatia, May 20–27, 1998
Nowy Sącz, Poland, July 17–24, 1997
Bratislava, Slovakia, October 9–13, 1996
Szeged, Hungary, May 29–June 3, 1995
Cluj-Napoca, Romania, May 27–31, 1994

The Baltic Olympiad in Informatics (BOI) was established on the initiative of three Baltic countries (Estonia, Latvia, and Lithuania) in 1995, and few years later, it was opened to all countries around the Baltic Sea (Poranen et al. 2009). The main goals concentrate on providing the participating students with experience of an international Olympiad, encouraging communication and exchange of ideas between the developers of national contests in informatics, as well as assisting delegation leaders in selecting participants for the IOI.

The BOI is a short-term (lasting 3–4 days) and inexpensive event. It can be distinguished for cozy and good neighborly atmosphere, which is highly important when motivating students for self-help.

Even though the BOI is a mini model of the IOI, it has significant differences from the cultural and learning perspectives. The organization of the scientific part of BOIs is based on mutual trust of the participating countries. The leaders of all the participating countries offer problems for the nearest BOI. At first draft task texts are offered, then the ideas are exchanged via e-mail and discussed, and some problems are rejected, while other problems

are suggested to be modified and later are accepted. Most of the problems are translated to the native languages by the leaders before going to the Olympiad. This is a unique possibility for country representatives to gain experience in organizing the scientific part of a small international Olympiad as well as to raise their qualifications in algorithms.

The organizers of BOIs try to follow as close as possible the newest IOI trends in problem types, compilers, platforms, and contest systems. Even though all the tasks are of the algorithmic nature, they represent cultural and methodical differences. Since in the BOI much preparatory work has been done in advance, team leaders can discuss the tasks, possible solutions, and technical issues, and the BOI can be considered as a pre-arranged international way of learning.

The first *Baltic Olympiad in Informatics* was held in 1995 in Tartu, Estonia, with three participating countries. Over the years, BOI has become an established event, and many new countries have joined the contest. 2017 is the first year BOI is held in Norway and the first time Iceland participates.

Tartu, Estonia, April 27–Mai 2, 2019
Stockholm, Sweden, April 27–Mai 2, 2018
Bergen, Norway, April 25–30, 2017
Helsinki, Finland, May 11–15, 2016
Warsaw, Poland, March 28–May 3, 2015
Palanga, Lithuania, April 26–30, 2014
Rostock, Germany, April 8–12, 2013
Ventspils, Latvia, May 3–7, 2012
Lyngby, Denmark, April 29–May 3, 2011
Tartu, Estonia, April 30–May 3, 2010
Stockholm, Sweden, April 18–22, 2009
Gdynia, Poland, April 17–23, 2008
Güstrow, Germany, April 24–28, 2007
Heinola, Finland, May 18–22, 2006
Pasvalys, Lithuania, May 5–9, 2005
Ventspils, Latvia, April 21–25, 2004
Tartu, Estonia, April 23–27, 2003
Vilnius, Lithuania, April 23–28, 2002
Sopot, Poland, June 16–21, 2001
Haninge, Sweden, July 31–August 4, 2000
Riga, Latvia, April 16–18, 1999
Tartu, Estonia, June 25–27, 1998
Vilnius, Lithuania, April 24–28, 1997
Riga, Latvia, April 18–20, 1996
Tartu, Estonia, April 21–23, 1995

National Olympiads have more complex infrastructure. Countries have different educational systems, but there are as many similarities as differences. Usually there are several rounds, e.g., school, regional, or state round. It is also common to use difficulty levels, e.g., junior and senior.

More than 40 countries published about their Olympiads in the IOI journal *Olympiads in Informatics*. volume 10 has a special issue focused only on teaching informatics and running contests in Russian Federation, and volume 11 has a special volume devoted mainly to informatics education in Iran.

Conclusions

Computers are becoming more and more frequently used in the education from kindergarten to high school. There is a general worry that all the millions of computers in schools and all the millions of smartphones are not used in a pedagogically meaningful way. Enormous computational power is in the idle mode because the teachers are not aware of the advances of the computer science and pedagogy.

Things can be improved, and in this entry we have emphasized the value of computer programming and attraction of computational thinking to bring a significant improvement in learning and teaching in schools. The success of the IOI and other local computer Olympiads have been very encouraging to really believe that computer programming is one of the tools which make a regular teacher's work more productive and meaningful. It can be seen that in many countries the local and national curriculum renewing initiatives the role of the computer science and computer programming are gaining weight reflecting the increasing demand of computer professionals in the country.

Contests play an important role as a tool of motivation and inspiration. In order to encourage students to learn computer science, we should look for attractive didactic forms. The Olympiad in informatics and the *Bebras* challenge on informatics and computational thinking could serve as useful examples.

Computer Olympiad is a globally recognized way to involve students into informatics and a very important motive to improve their programming skills. There is a steady infrastructure of the IOI. A community of researchers, teachers, and other professionals in education has been formed too. The regional Olympiads are organized following the same principles. Similar Olympiad movements exist in many countries. Various difficulty levels in national Olympiads render a possibility for the students with different experience and knowledge of programming to participate in the event. Even the beginners in programming can acquire motivation to participate and to learn. Olympiads are mainly focused on algorithms design and programming. Actually, tasks are rather difficult for many school students and require continuous efforts.

Let's take Olympiads and contests in informatics as a serious didactical approach of computer science education and support them with learning material, tools, teacher training courses, etc. Olympic and contest communities are open for proposals and ideas for collaboration and future developments. Involving pupils in recognition of informatics as a science discipline should be our target, and we should try to achieve it together. Well-organized contests with interesting, playful, exciting problems and attractive awards will involve school students into the essence of the computer science world and will help to understand the realities, possibilities, and failings of the technology.

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International Reports (Including OECD)

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Introduction

Since the 1980s, the production of international reports on education has increased sixfold (see Fig. 1). From a handful of reports published per decade in the second half of the twentieth century, they have rapidly increased in number and gone from reporting on educational attainment from a dozen European countries to over 70 countries and educational systems for test-based reports (NCES 2019). Meta-studies such as the United Nations Educational, Scientific and Cultural Organization’s (UNESCO) Global Education Monitoring Report analyses data (or the absence of) from over 240 countries (UNESCO 2018). Yet despite being a relatively recent phenomenon, international reports on education and the organizations that publish them have become increasingly influential in the economic, political, and professional decision-making processes of governmental educational reform (Hamilton 2017).

These reports can be understood as documents that seek to provide information about national education systems across groups of countries or regions (such as Chinese Taipei, Hong Kong, Belgium Flanders, or Northern Ireland). While they can vary in both form and rationale, most reports serve as policy instruments that place an emphasis on analyzing the differences and similarities found in educational provision and attainment within and across educational systems with an aim to make recommendations that draw upon on these comparisons.

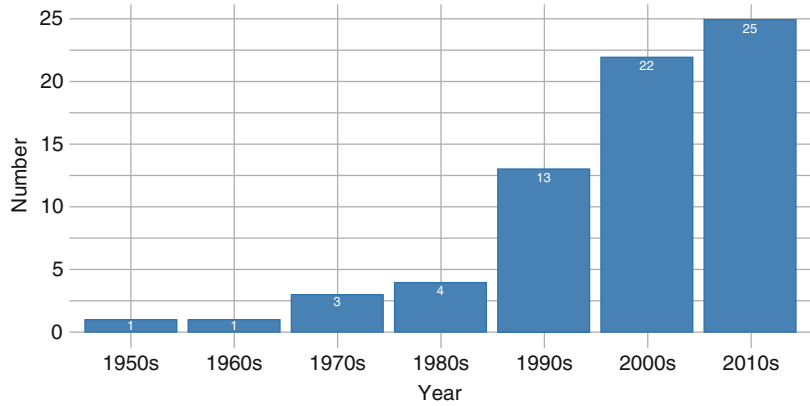
To accomplish this, they describe the characteristics of those organizations that provide schooling and training at the various levels of formal and compulsory education, as well as producing data on the resources, approaches, and strategies employed in each country or region. In addition to measuring characteristics such as access rates and demographic data, the majority of international reports focus on educational attainment, with the primary, tertiary, and post-secondary sectors often receiving the most attention. Since the actors producing these reports seek to either influence national or transnational spending and policy-making within state or international entities, the reports focus almost exclusively on state- or publicly provided educational systems. Education and training offered by privately funded or vocational training sectors receive relatively little in the way of coverage. Although the actors authoring many reports often frame the rationale and findings as being internationally relevant, the analysis and policy recommendations are centered on nation states or individual regions as either partners or competitors in a global economy.

Background

In Europe, many governments, from the late eighteenth century onward, began developing and expanding their national education and vocational training systems. This was in response to changing labor market demands made by state bureaucracies and industries for a workforce that was better educated and trained.

International Reports (Including OECD),

Fig. 1 International reports on education produced between 1959 and 2019. (Source file: intReports60years730x365.eps)



As such, this meant that the need for data on education and training increased, leading to an increase in the demand for reports on the ability of educational systems to respond to these changing demands.

Initially, reports on educational provision and attainment were, for the most part, created and published by national governments using data produced by national statistics agencies or the schools themselves. In the nineteenth century, reports or studies on educational systems tended to be isolated publications with relatively limited influence or institutional support (Cardoso and Steiner-Khamsi 2017). Although the development of standardized indicators against which various educational statistics could be measured (access, gender ratios, teacher pay, graduation rates, etc.) had already been well-established since the nineteenth century, such data production exercises were heavily adapted to institutional, national, or regional contexts with little in the way of coordinated international harmonization or standardization.

Often commissioned on an ad hoc basis, early international reports were typically isolated efforts and not part of coordinated global effort to systematically standardize educational data production for the purposes of policy borrowing or learning. They focused on the international dimension insofar as they sought to modify local conditions within national or regional boundaries and did not aim to affect change or influence education across national or regional boundaries.

International Educational Reporting and ILSAs

The expansion of national education systems during the twentieth century was accompanied by the consolidation of comparative education into a discipline with the creation of journals, international professional societies, and university departments. The University of London's Institute of Education and the Teachers College at Columbia University's International Institute both published educational yearbooks that compiled national reports on educational issues ranging from the church and state to curriculum (Bereday 1957). The years following the Second World War saw an intensification of reporting with the start of UNESCO's *World Survey of Education* (UNESCO 1955). Unlike previous yearbooks or reports, UNESCO's coverage was broader (197 member states) and sought to directly influence policy through the articulation of universal educational goals, such as free and compulsory primary education (King 2016). The trend toward international reports on education that linked global targets and statistics continued in the late 1950s, when members of the United Nations Educational, Scientific and Cultural Organization (UNESCO) began working on what would later become the International Association for the Evaluation of Educational Achievement (IEA).

The IEA's mission was to create a laboratory for investigating for what it termed the "determinants of educational outcomes and comparing

them across nations with the express aim of revealing important relationships that would otherwise escape detection within a single education system” (de Landsheere 1997, p. 1). Where the IEA broke with the tradition of earlier reports was its extensive coordination and organization of international governments and agencies, with the aim of comparing educational practices. Perhaps even more critically, the IEA reinforced and naturalized the close alignment of reporting with educational testing. The IEA created two core assessment activities, Trends in International Mathematics and Science Study (TIMSS) and Progress in International Reading Literacy Study (PIRLS). These international large-scale assessments (ILSAs) produced data on literacy and numeracy levels within national populations that were linked to internationally comparable scales. In moving toward the inclusion of standardized test data into international reports, the IEA also began the work of formalizing and operationalizing the concepts of literacy and numeracy as measurable psychological constructs or skills.

This process of internationalization and standard setting was intensified in the 2000s. Transnational organizations such as the Organisation for Economic Co-operation and Development (OECD), UNESCO, the World Bank, and the European Union (EU) sought to normalize reporting and prioritized international standards that could be “borrowed” by national governments for the purposes of policy decisions (Steiner-Khamsi and Waldow 2012). The EU’s Lisbon Agenda in 2000 reinforced the link between education and the role of indicators in the measurement of lifelong learning outcomes as a measure of economic competitiveness (Ertl 2006). Similarly, in 2015, the inclusion of educational provision and attainment into the United Nation’s sustainable development goals countries receiving financial aid were expected to modify educational provision in alignment with broader economic development targets (UIS 2016). This further strengthened the link between test data and indicators produced by international reports to the funding and accountability measures and gave reports an even greater role as key reference documents in debates and

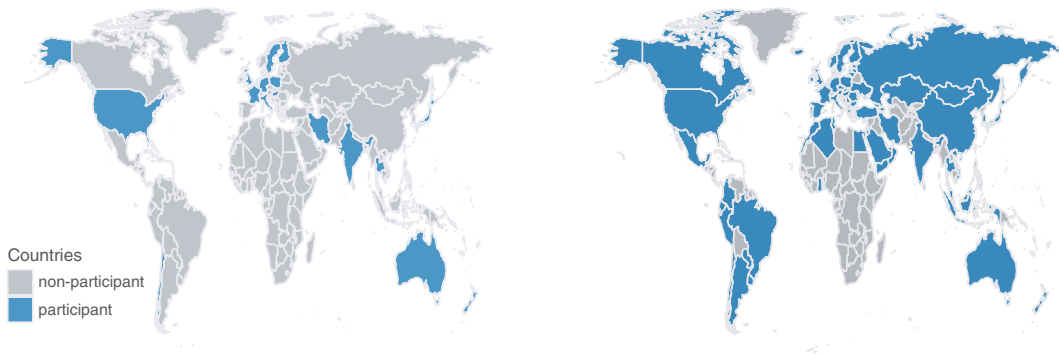
decision-making regarding educational provision and spending priorities.

At the forefront of this was the OECD. In the 1990s, the OECD began positioning itself as an actor in the production and analysis of educational indicators as a way of measuring a member state’s economic development. In 2000, the Programme for International Student Assessment (PISA) extended the work of the IEA’s test-based reporting to make literacy and numeracy skills that could be measured independently of national or institutional contexts. In doing so, the OECD produced international reports that were less driven by the research-oriented comparative education agenda of the IEA universities but by a political and econometric framework that situated reports as policy instruments that sought to align educational attainment with economic indicators such as gross domestic product (GDP) to measure human capital development. In this way, international reports were able to provide national governments as well as transnational agencies such as the UN, the World Trade Organization (WTO), or the World Bank with data on education that could be measured against other economic indicators.

The OECD intensified test-based reporting by expanding the number of countries with industrialized economies with regular PISA deployments. It also developed the scope of testing and reporting with adult skills’ reports, beginning with the International Adult Literacy Survey that later became the Adult Literacy and Lifeskills Survey with the Programme for the International Assessment of Adult Competencies (PIAAC) extending the range of PISA surveys. Critically, the OECD was able to establish itself as an influential actor in a network of testing agencies (Educational Testing Services, Pearson, Australian Council for Educational Research, IEA) and international organizations (EU, Statistics Canada, UNESCO-UIS) that reformulated educational attainment as human capital, or skills, that could be measured with sophisticated psychometric technologies. As these test-based reports have become increasingly naturalized, the number of countries participating in the data production for reports has also grown (see Fig. 2).

1959–1969

2010–2019



International Reports (Including OECD), Fig. 2 Countries participating in test-based international reports

This move toward a psycho-econometric modelling of education from a socially and culturally situated conceptual framework allowed reports to be used as policy instruments by nations or regions to benchmark their own systems in context, where national education systems competed to be the highest scoring performers in a global knowledge economy. In order to achieve this shift, reports became increasingly statistical in nature and relied heavily on the use of surveys and psychometric educational testing to produce norm-referenced assessment data. The move toward data-driven and technocratic reports gradually superseded humanist and emancipatory discourse of UNESCO's Faure (1972) and Delors (1998) reports on international education. As a result, international reports on education are now almost indissociable from ILSA-based reports that formulate educational attainment, chiefly as skills acquisition. ILSAs focus on the role that education has to play in the production of data on internationally comparable skills as proxy measures for economic competitiveness. This narrative has come to dominate the rationale for reporting on education and led to the marginalization of reports that emphasize cultural differences and non-economistic goals (Addey et al. 2017).

Digital Technologies and International Reports

A more recent trend in the development of international reports has been the increased use

of and exploration of uses of digital technologies. From the initial stages of data production and analysis, to the eventual publication and communication of the findings, digital technologies have played an increasingly significant role in transforming the character and reach of international reports on education.

The OECD's PIAAC, published in 2012, was the first report to rely almost exclusively on a digital test and survey tool for its core data production and analysis (OECD 2013). Although PISA 2006 used computers to test science skills, PIAAC was an important test case for the use of digital technologies for the automation of data production. With its successful implementation, PISA 2015 and PIRLS 2016 (or ePIRLS) have also been digitalized with all subsequent deployments of these reports, with certain exceptions, following this trend. The move away from traditional "paper and pen" or printed approaches for the data production of international reports has happened for several reasons.

First, since students are interviewed and tested using digital devices such as tablets or laptops, sampling accuracy, data security, integrity, and transfer to data storage are easier to control. As much of the data are drawn from cognitive tests, personality surveys, or background questionnaires, digital technologies are able to process and score results with greater precision and rapidity and greatly reduce human error or falsified data. Furthermore, digital tests are able to apply sophisticated algorithms that select and adapt test and survey

questions with speeds and agility unmatched by a human being. These algorithms, by adapting to a respondent's answers or background variables – such as educational level, cognitive test scores, nationality, and so on – allow test makers to reduce inaccurate results caused by test fatigue as well as increase the scope of the domains tested and the populations sampled.

Measuring Digital Skills

One of the more novel aspects of the digitalization of international reports is the role it plays in innovating in the type of data that can be produced and reported on. Tests such as PIAAC began expanding the range of concepts to be measured by introducing a test called Problem Solving in Technology Rich Environments (PSTRE) to evaluate the digital skills of workers in OECD economies. Similarly, PISA 2015 and ePIRLS used items that tested the ability of school-age children on their ability to retrieve and process information found in digital environments, such as websites or digital documents. In many ways, the digitalization of report data production is a consequence of the world that the reports describe. PISA 2018's objective is to report to what extent children have “global competence” or the ability to understand and engage in local, global, and intercultural issues. To do this, students are tested on their ability to capitalize on digital spaces and use online media to communicate with others. As with PIAAC's PSTRE evaluation, the inclusion of digital skills in international reports is a response to concerns about a “digital skills gap” or the belief that adults and children lack the skills to navigate a world where being able to use digital technologies is portrayed as being indispensable to participating in society. These tests all attempt to measure, albeit in standardized simulations, “real-world” problems that can be used to report on real-world skill deficits or abundance. These data are then used to translate the performance of the “right skills” in tests into economic indicators. This in turn provides evidence that can be used in international reports that are oriented toward analyzing the relationship between both schooling

and higher education and the ability of citizens to participate in “an increasingly digital and globalised world and for countries to promote inclusive labour markets and to spur innovation, productivity and growth” (OECD 2016b).

Third, the move toward asynchronous and remote testing that requires minimal or no human supervision and dispenses with the time-consuming and complicated spatio-material configuration of schools and equipment allows international agencies to increase number of educational providers contributing data by reducing participation costs through digital delivery. As such, the “dematerialization” of international reports has led to the development of micro-ILSAs. These tests are smaller versions of the main tests but draw extensively from the same statistical, conceptual, and operational technologies. Unlike ILSAs that are performed at a ministerial level, these micro-ILSAs are testing and reporting tools that are pay-per-use and deployed on demand by whichever entity meets the technical and financial prerequisites. The OECD's PISA for schools, like the main test, produces data and reports on 15-year-old school students but differs significantly in some key ways. PISA for schools allows schools to generate their own reports and data on an individual student's ability and thus moves away from the logic of anonymized low-stakes testing for individuals. Unlike the main test, it also encourages schools to use the data produced in the reports to implement curriculum change and classroom practice. Furthermore, the test gives access to an online platform that allows schools to compare results with other schools and countries and engage in school-level policy borrowing and learning. That is, schools can choose the features of the other educational systems that have higher test results and use or “borrow” educational practices to change local-level school policy (Lingard 2010) and align themselves to international practices. ESONline, a pay-per-use version of PIAAC developed by the OECD and the EU, performs a similar role for prisons, research centers, refugee centers, or private companies that wish to produce reports that measure the skill levels of targeted adult populations (OECD 2016a). These reporting tools, deployed outside of the regular 3-year cycles

of the main tests, allow participating schools and organizations to link their customized reports to international benchmarks, standards, and results. They also provide the OECD and its partner organizations with an almost entirely automated flow of data allowing it to refine and adapt its psychometric and economic models of education.

Digital Publication of International Reports and Datasets

The digitalization of reporting is perhaps more obvious in report publication. International organizations have recently been complementing the more traditional book format of reports by investing in websites where data on indicators are continually updated and accompanied by data displays and visualizations that facilitate dissemination by the media and governments. The World Bank's Education Statistics (World Bank 2018) website aggregates data produced by UNESCO's Institute of Statistics (UIS) (UIS-UNESCO 2018), the IEA, and the OECD. Rather than waiting for the publication of a report, visitors can consult data tables, maps, and displays on learning outcomes, educational attainment, quality, expenditures, and policy. The OECD's Education Global Positioning System (GPS) (OECD 2018) provides similar data explorers that generate data visualizations that rank countries on their international performance. In addition to the graphical representations of educational indicators, both organizations allow visitors to download datasets. Although some data are relatively simple to read and available in spreadsheet form, most of the educational data found in reports require the use of specialized statistical software such as the Statistical Package for the Social Sciences (SPSS) in conjunction with the IEA's *International Database Analyzer* software package (IEA 2014). These datasets, primarily intended for use by researchers, government employees, or journalists, extend the scope of reports on educational system planning and policy by the use of these data in articles, whitepapers, and scholarly publications.

Conclusion

Due to the considerable time, expense and expertise demanded from the network of scientific, business, and governmental actors required to produce international reports on education, a relatively small group of actors are involved in their production. These are, unsurprisingly, international or transnational organizations such as the OECD, UNESCO, the EC, the World Bank, and the IEA, whose reporting activities are financed and commissioned by the national governments that fund them. A notable exception to this is the McKinsey Consulting Group that produces independent international reports on education. Even so, in recent years, the OECD and IEA have acquired a quasi-monopoly on test data-based reports. The UIS's Literacy Assessment And Monitoring Programme (LAMP) which aimed to produce IALS-like data for developing countries from 2003–2011 has been discontinued and replaced with survey data. The World Bank's Skills Toward Employability and Productivity (STEP) test that measured and reported on workforce competencies and skills acquisition in 2010 has never seen subsequent iterations. The World Bank now draws extensively upon OECD and IEA data for educational or human capital reporting.

However, since the creation of reports is concentrated in the hands of a relatively small number of organizations, however large in size, a certain consensus on how to understand educational attainment and intervention has evolved. This can be characterized in a number of ways. First, skills and outcome-based education is seen less as an emancipatory process than as an economic one. That is, investments into education and training are seen as inputs that produce different levels of human capital and as such increase or decrease a nation state's economic competitiveness and capability to innovate and produce. Alternative visions of how to report on education, such as the UNESCO's Global Education Monitoring (GEM) Report, are less focused on tracking skills levels than engaging with specific themes such as migration, the environment, conflict, inclusion, or other issues to ensure that the right to education is achievable.

Although these reports influence policy decisions, particularly in regard to sustainable development goals for education, they do not have the same weight in political discourse and in media representations as test-based reports. The GEM reports lack the affective force or “shock factor” of the statistical educational league tables produced by test-based reports that frame education as a crisis and, as such, they lack the same impact and ability to act as agents of policy change.

The last 30 years has seen international test-based reporting grow in influence. However, this kind of reporting has certain limitations. Part of the success of this style of reporting is in its ability to produce quantitative and standardized data on educational outcomes. In this way, it is part of an already well-established project of government and private actors to produce and leverage quantitative data on many aspects of citizens’ lives beyond education. However, this is also one of its limitations, as seen in the OECD’s failed attempt to extend this style of reporting to the higher education sector with Assessment of Learning Outcomes in Higher Education (AHELO) in 2012. The ability to report on sophisticated skills and knowledge is not something that large-scale tests can do easily – spoken and written production are all absent from such international scale reports into education. Similarly, international reporting can ignore or have difficulty integrating the role of local histories and cultures that can be important determinants of successful educational outcomes. The “culture-free” dimension of international reports has often led to failed or counterproductive policy borrowing. Nevertheless, with the intensification, digitalization, and ubiquity of quantitative data production, the statistical and test-driven character of international reports on education looks to have a stable future in the years to come.

Cross-References

- [Educational Assessment, Educational Data Mining, and Learning Analytics](#)
- [Information Technology and Assessment](#)
- [Policy Rationales and Integration Rationales, Implications for Subject Area Teaching](#)

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IT in Educational Institutions, Planning and Development of

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Definition

Planning and development of information technology (IT) in educational institutions consists of a set of activities aimed at identifying what the future information architecture of an education center should be. During this process, the IT applications that can most effectively contribute to the achievement of the center's mission and objectives are identified; the order in which the candidate applications are developed is also

prioritized, and the volume of investment in them is decided, as well as the most appropriate development methodology to ensure the success of the project.

Introduction

There are numerous evidences that demonstrate the need to carry out organized processes of IT planning and development in organizations (Marabelli and Galliers 2017; Kumar 2015). Sometimes this process is not carried out in an orderly manner; money is invested in technology to solve specific problems that may not be useful in the long term for responding to information needs. In addition, the disorganized implementation of IT can lead to problems of duplication, incompatibility, and premature technology obsolescence (Kumar 2015). Education centers represent a type of organization in which there is a need to carry out organized IT planning and development processes. This need is the result of a series of characteristics, including (a) the handling of a large amount of teaching, administrative, and personal information, which obliges them to comply with requirements related to privacy and ethics in the use of the IT; (b) limited economic resources, which implies the need to rationalize investments, including in technology; and (c) although a large number of education centers are not run for business purposes, they nevertheless do play an important social role and have a mission and objectives to fulfill.

To this, we must add the varying nature of the educational training offered according to the type of center. Schools and high schools share a similar mission, fundamentally based on the teaching of concepts, although with different methodologies according to the age of the students. Vocational training centers have, basically, a “professionalizing” mission, based mainly on a practical education oriented toward training professionals who will mostly perform “blue-collar” type jobs. Universities and colleges share a professionalizing and research mission, where theoretical and practical training is combined, oriented fundamentally toward training professionals who will mostly take up professions of the “white-collar”

variety. This different conceptualization of education centers adds a challenge when establishing IT planning and development processes.

Another factor of added complexity is the low level of familiarity of many educational managers with IT. This fact means that, frequently, the function of coordinating the planning and development of IT is delegated to third parties (Marabelli and Galliers 2017). In this way, the overall vision regarding the direction of education centers is lost, and the planning and development of IT is a poorly organized process, even, at times, chaotic. This multidimensional problem hinders the proposal of an integrating model for the planning and development of IT in educational institutions. The availability of a conceptual framework that guides this type of process could be very useful for educational managers in facing this type of challenge with certain guarantees of success.

The field of education can benefit from techniques and tools related to the planning and development of IT that have been widely verified in other organizations. The accumulated experience in this area by many education centers, especially universities, can also be taken advantage of. The greater relative size of universities has meant that, for decades, they have had experience in the problem of IT implementation. In order to provide an integrative proposal for the planning and development of IT in education centers, a broadly verified and simple approach is presented below. The proposal is based on an information architecture planning model rooted in IT application portfolio matrices. This model is characterized by a broad capacity to adapt to different situations and scenarios, having demonstrated its practical usefulness. This is due, in large part, to the extensive experience accumulated over time of its use in all types of organizations. In the following sections, the proposed approach will be described, and it will be particularized for different educational levels.

Information Architecture and Planning

Planning, simply put, is deciding what to do before taking any action (Reynolds 1992). An IT

plan is needed to guide all economic, human, and material efforts to achieve effective information management in an organization. The IT plan defines what projects to develop and at what time. It also serves as a reference to justify the use of scarce resources at an organization. The existence of an IT plan can even serve as an argument to help management stop a project already under way if the project is not consistent with the overall plan (Reynolds 1992). In organizations, as in education centers, the IT plan must be consistent with the mission, objectives, and maturity of its IT infrastructure. A first requirement for a successful plan is that the participants agree on the scope, deadlines, and expected results (Peppard et al. 2014). In the educational arena, the center's management team is responsible for establishing these parameters, alone or in cooperation with other agents or advisors, both internal and external, to support the planning process. In this part, it is very useful to establish the reasons that justify the development of an IT plan. Among these reasons may be dissatisfaction with the current management of information at the center, a change in the mission or its objectives, the updating of a previous IT plan, etc. Another relevant factor that justifies IT planning is the identification of trends in the educational field and in technology to support the teaching-learning and data management processes (student records, academic performance records, etc.). Understanding the changes that are taking place in the education sector and how they can affect educational institutions may be the key for the plan to be able to respond to challenges in the environment. The IT plan must explicitly incorporate how to respond to these identified external trends.

The IT plan should also consider the current situation of the education center in terms of IT infrastructure and maturity in the use of said infrastructure. The degree of response to external IT challenges will depend on the level of internal development. For this reason, the proposals emanating from the plan must be realistic and coherent with the current situation of the center. If the degree of development and maturity of IT does not allow an immediate response to trends in the educational environment, then this fact should be

considered in the plan. In this case, it would be necessary to establish actions to cover this gap between the internal situation and the challenges that are to be faced or to reformulate the objectives of the IT plan. From the conjunction of the elements that converge at the education center (mission, objectives, trends in the educational environment, IT situation, etc.), a set of potential IT projects will arise that will constitute their future information architecture (Chan and Reich 2007; Ward et al. 1990).

The architecture of applications is a table that aims to reflect and classify the applications that must be developed or improved according to the information needs of an organization. A useful way to represent the information architecture is through the concept of an application portfolio matrix. Each IT application can be positioned in the cell of an array according to its potential contribution to the organization. The advantage of this approach is that, according to the cell occupied by the application, there are generic recommendations that can be helpful in making decisions about IT. These may be decisions of the following type: (a) relative volume of investment, (b) priority in the order of development of the IT applications, (c) method for the development of the application, (d) more appropriate information technology, and (e) form of IT management once it is operational. Despite the utility that these tools can offer, it is necessary that their adoption be carried out with caution, since what is offered are generic recommendations. However, it cannot be forgotten that it is necessary in each specific case to evaluate the different alternatives and carefully study the implications of the decisions to be made.

Application Portfolio Matrices

As a result of IT planning, it may be concluded that there are several IT applications that should be carried out to cover current and future needs. If the education center has a strong innovative vocation and uses IT as a strategic instrument in its operation, then the number of resulting applications may be high. At this point, the problem of limited

resources arises, which forces management teams to select applications based on their usefulness, associated costs, capacity, etc. There are many variables involved that complicate the process of deciding which applications will be given the time and resources needed to develop them and which others should wait, or even be discarded. To try to facilitate this decision process, the application portfolio matrices have been designed. Basically, they are two-dimensional matrices in which, depending on two simple variables or two aggregate variables (the latter resulting from the weighted combination of several simple variables), the computer application is located in a quadrant of the matrix according to the score it achieves in relation to the defined variables. Depending on this position, experience has allowed the development of generic recommendations that may be applicable for each case. The advantage of application portfolios lies in their apparent simplicity and the capacity for systematization they offer, based on well-defined significant variables. Their usefulness is evident in facilitating what in principle constitutes a task of rationalization and complex decision-making, and that can have strong repercussions for the organization (Tukana and Weber 1996).

One of the matrices of the application portfolio that has most proven its usefulness in facilitating decision-making in IT is the one developed by McFarlan et al. (1983) and adapted by Ward et al. (1990) and other authors (e.g. Wijaya 2016) (Fig. 1). This matrix has as its main feature the fact that it links IT applications with the contribution they make to the functioning of the organization – that is, technical aspects are combined with others of an organizational nature. This ensures a basic premise that should guide any process of IT planning in organizations, which is that utility should always prevail in terms of organization or, to put it another way, technology is only a means to an end. The above is also applicable to education centers, where objectives related to improving the teaching-learning processes and the management of academic and personal data must prevail over purely technological considerations. In the educational environment, the application portfolio matrix allows IT applications to be located on

the basis of the present contribution they may have for carrying out activities and the future contribution that can be expected in a given time horizon (Wijaya 2016). Using both variables, the different IT applications can be located in one of the four cells that it incorporates. Each of the quadrants in the matrix is given a denomination in order to designate the applications that fall within its category. These denominations are the following:

- *Support*. Applications that improve administration and results but are not critical for the organization, since it could carry out its activities almost normally in the event that these applications were not available. Basically, these are applications that facilitate or speed up tasks, generally from a purely operational point of view.
- *Factory*. This group includes those applications that are essential for performing the operations of the organization. They are so important that they have become critical and the organization would encounter serious difficulties if the application stopped working, even for a small period, or if anomalies were detected that made the validity of the information doubtful.
- *Strategic*. These are critical applications for future success and of great importance in the present. It could be that the organization already had some IT application in this group, but it is usually foreseeable that the application will take another form in the future or that it will be presented in a format that also includes other functions or technical advances that make it more versatile and important.
- *High potential*. Applications that may be of future strategic importance, but that currently do not have enough importance to support the activities of the organization. In short, these are potential developments with a high level of uncertainty, since their justification is based on the contribution that could be made in the long term.

Below are generic considerations associated with IT applications according to the cell of the

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Fig. 1 Application portfolio matrix. (Source: McFarlan et al. (1983) and Ward et al. (1990))

FUTURE CONTRIBUTION

High	Strategic	High potential
Low	Factory	Support
	High	Low

PRESENT CONTRIBUTION

application portfolio matrix adapted to the field of education:

- *Support applications.* Within this category, all the applications that are important for the operation and administration of education centers are framed, although they are not critical because they could continue their operation for a long period of time without them. The second characteristic of these applications is that they are often applications common to all educational centers, so that there can be hardly any differentiation based on the use of this type of application.
 - *Software packages.* Due to the general nature of the activities to be supported, there are many software packages available on the market that can serve this purpose. It is convenient to select applications with a well-established client base that have already been tested, avoiding being the first to use an application.
 - *Functional complexity.* The support applications are characterized by being easy to use because they usually work in isolation, so that an error in one of them does not affect the rest of the IT applications at the center.
 - *Skills.* As these types of applications are usually based on a standard software package, it is not generally necessary to possess high levels of technical skill for their use.
 - *Computational capacity.* The need, in terms of capacity, of most support applications is, in general, completely predictable, which makes it difficult for computer equipment to crash due to inefficiencies in processing capacity.
- *Risk.* With this type of application, no kind of technical risk should be introduced. The software/hardware used may be something new for the center, but it must not be new for the supplier, who must be prepared to deal with any possible incident.
- *Divestment.* These systems, because they are not critical to the center, are candidates for elimination. There may be arguments that justify the subcontracting of this kind of system operation to third parties, in the form of outsourcing, which are advisable to consider.
- *Factory applications.* These applications are vital for the present functioning of the education center.
 - *Software packages.* The factory applications are usually specific to the sector of activity, and even specific to the education center (e.g., college or university) based on the way in which activities are carried out. Although there are standard packages, they are fewer in number and more specific than those available for support-type tasks. Because the integration of data is a key aspect in factory systems, the databases from which they are fed must be highly consistent.
 - *Functional complexity.* Factory applications tend to be functionally complex; they are characterized by having dependencies on other programs, in such a way that any change can affect other applications in

domino effect. If standard computer packages are used and modifications are made to adapt them to the specific needs of the education center, it is necessary to thoroughly check the changes so that the system works and no failures appear.

- *Skills.* This class of application will require modifications to meet the changing needs that may arise at educational institutions. Therefore, a high level of skill will be required by the technical support managers. In this sense, updates to the program are very important and have to be verified and evaluated after introduction. The people responsible for adaptation, whether they are internal or external to the center, must be highly qualified.
- *Computational capacity.* The availability of the system is critical; this means having an up-to-date backup and all the essential components, both hardware and software, should be duplicated or ready to be replaced quickly if problems arise. Capacity planning should be based on peak loads that ensure the response of the system, even in extreme conditions.
- *Risk.* It is important that these systems do not fail; one way to reduce unnecessary risks is to avoid technological innovation in the area of factory applications. The general rule should be to make changes in the technology used only if it has been extensively tested. In case of use of a new IT application that replaces the previous one, the operation of both systems should be carried out in parallel for a time to ensure that the new system works satisfactorily.
- *Strategic systems.* They are those that should allow the education center to stand out in some way over others. It is likely to mean a change in the way the center is operated or controlled. It can also happen that the advantages are not lasting and that, in addition, the application needs continuous improvements to allow it to continue gaining advantage in the future, which brings with it a great deal of expense. Many aspects of technology management associated with strategic systems are very

similar to factory applications, although the biggest difference lies in the need to take risks.

- *Software packages.* It is unlikely that commercial software packages exist for this type of application. If they did, a short-lived advantage could possibly be achieved by being the first user of the package (the sustained advantage comes from the unique character of the IT application, which others cannot easily copy or improve).
- *Functional complexity.* It is likely that these systems are complex or become complex as functions are added to them. Ideally, the system should be tested to ensure the tightness of the risk before implementing it at the operational level.
- *Skills.* Considerable technical and organizational skills are required for its development and implementation. It is important that there is continuity with the members of the technical team in order to conserve knowledge about the mode of operation of the application, given that this context does not facilitate the generation of exhaustive documentation on how to operate it.
- *Data sources and dependence on other systems.* The data in the strategic applications need to be integrated with other systems at the center; they can also take data from external sources. Sometimes, strategic systems are based on existing applications, such as factory or support types. It is important that these last ones are stable and robust applications because, if, on the contrary, they are unstable, the new strategic applications will inevitably expose those weaknesses and cause the systems to crash.
- *Computational capacity.* In direct contrast to factory and support applications, the computational capacity requirements for strategic applications are often very difficult to determine. Therefore, it is advisable to use equipment that allows an increase in capacity or technological updating.
- *Risk.* The projects included in this category are clearly high risk; this is due to the direct relationship between risk and potential

benefits. The risks involved are of a technical or organizational nature, due to the fact that the center may be entering into new, less experienced technological areas, and also in combination with relatively significant changes in working methods (of students, teaching or administration staff).

- *Implications for planning.* A continually updated knowledge about IT trends in the education sector is important to avoid being surprised by other innovative centers. It is also important to develop these applications quickly because the possibility of achieving advantages can be fleeting or short-lived.
- *High potential applications.* They are innovative applications that, eventually, could be of great future importance. An application should only be in this part of the matrix for a limited period until its future is clarified. To facilitate their development and management, the most appropriate course of action is to select a project leader (some member of the teaching or administrative staff), supported by the center's management and with sufficient technical skills to work in a close relationship with the technicians. Before a technology "abandons" the high potential cell, any error or failure should be completely corrected, given the risk that a failure will drag down the rest of the applications. If the education center wishes to stand out from others, it should consider investing in this type of IT application, since if it does not act in this way, it runs the risk that the possibilities to stand out for its IT are limited by a set of outdated technologies and skills.
- *Software packages.* The computer applications that can be found on the market correspond to very novel systems that have not yet been exploited commercially on a large scale, so there is the possibility of obtaining advantages derived from being the first to use this technology.
- *Functional complexity.* These applications have a high level of complexity because they normally support processes whose difficulty in automating has usually been the reason underlying the absence of computer applications to carry them out or because of

new technology that, due to lack of operational knowledge, is often difficult to assimilate.

- *Skills.* Given their innovative nature, these applications require highly qualified personnel, which means updating the training of the center's staff or hiring the support services of leading technology companies.
- *Computational capacity.* It is difficult to identify what will be the capacity needed for the high potential infrastructure, since there is doubt as to whether the applications will be useful for the center in the future or, on the contrary, they will be abandoned. For this reason, it is convenient to use incremental technology, which can be adapted to future growth of the system as the demand for use in the center increases.
- *Risk.* These applications, by their very nature, are of high risk, so it must be assumed as natural that technical glitches and crashes occur, although this should not affect the operation of the educational institutions. That is, the risks should only affect the system under test, keeping it insulated as much as possible from other applications of common use.

Administration (Investment and Priorities) and Development of IT Applications

Decisions about what amounts to invest in IT infrastructure or what should be purchased first can be difficult to make and even become a source of conflict if there is no well-founded justification to support them. In addition, there is the condition of the low level of funding that usually characterizes educational institutions. Numerous techniques offer a reference on which investment decisions to argue for, although it is true that they are mostly oriented to users well versed in technical-financial concepts. This complexity often results in the management of education centers, for lack of knowledge of IT, preferring to leave the IT investment chapter in the hands of third parties, sometimes even external to the

center. For this reason, it is convenient to offer tools that, although they do not have a high level of mathematical rigor, are sufficiently valid and, above all, intuitive enough to allow this process to be led by the center's management.

Investment in IT infrastructure competes with other alternative investments, such as in real estate (new or renovations), equipment for classrooms or laboratories, office supplies, hiring teaching or administrative staff, etc. It is necessary, therefore, to establish a basis on which to evaluate IT investments. Investments in IT in the educational field should not be considered only based on the argument for the benefits that are going to be generated, which are usually very difficult to quantify, but on how they can serve to support the functions of the education center.

The application portfolio matrix provides a support framework for recommending generic guidelines for action on investments and priorities, in which the justification for developing an IT application and investing funds in it depends on the matrix cell in which it is located. This portfolio approach implies that the quantitative justification of the applications is easier in the *support* and *factory* quadrants, while for the *strategic* and *high potential* cells, the justification must be based more on qualitative considerations related to the future objectives of the center. Below is a set of recommendations for which is the most appropriate cost-benefit evaluation system for each case.

- *Support applications.* The main reason for its existence is the improvement of efficiency, which should be quantifiable and become a financial argument for investments. If the application contends with others for the limited resources available, then a supporting application must show a good economic return for the allocation of scarce resources. However, if IT investment capacity exists in a decentralized manner, the corresponding department of the center can assume responsibility for the investment in an application of this type.
- *Factory applications.* As for support systems, it is recommended that benefits (tangible and intangible) or costs be estimated before allocating any resource. In general, a feasibility

study is appropriate in order to find the best solution among a range of alternatives, each with different costs, risks, and benefits. However, some forethought must be demonstrated with the results because this may be inappropriate for factory applications, where the most economical solution may not be the most effective.

- *Strategic applications.* The fact that an application is considered strategic implies that it is considered important, even essential, for the achievement of the center's objectives, especially in the long term. With this type of application, the benefits have to be estimated approximately because it is difficult to adapt an estimate based on the calculation of benefits and costs that can be generated. Therefore, an application will receive the approval (or not) to be developed based on the decision of whether it is relevant to the objectives of the center. The key aspect is whether the management judges the investment as appropriate. In this sense, the critical factor is to allocate resources enough to carry out the development and achieve the objectives within the appropriate time horizon.
- *High potential applications.* The main essence of high potential projects is that the benefits are unknown, the objective being to identify the potentially achievable benefits. It is the R&D segment of the matrix and should be justified on the same basis as any other R&D development. This case is especially applicable to colleges and universities. When the allocations are made, the subsequent sums invested must again be justified and not simply assigned with the vague hope of eventual success. In general terms, investments in IT should be as objectively and subjectively considered as the center's other investments.

Once the evaluation of the likely costs and benefits associated with the applications susceptible to being developed or improved is made, it is necessary to establish priorities between applications when, for reasons of limited resources, not all can be installed at the same time. It is important to introduce a consistent and rational approach to the establishment of priorities if a successful implementation is desired. This is because if

priorities are based on changing and temporary aspects, planning will be meaningless. Using the approximation of the application portfolio matrix, the following conclusions can be drawn:

- *Support applications.* The establishment of priorities is fundamentally based on the fact that those with the greatest benefits (teaching, administrative) that use the fewest resources should have the highest priority.
 - *Factory applications.* The arguments for the assignment of priorities include (a) improvement of the teaching-learning process, (b) improvement of administrative processes, (c) improvement of IT infrastructure, and (d) others. Each of these aspects must be assigned some form of relative weighting so that an order of preference can be decided.
 - *Strategic applications.* Within this segment, the rational basis is based on prioritizing those applications that contribute most toward making the education center stand out from others and, in addition, require fewer resources to develop.
 - *High potential applications.* They are difficult to prioritize and will tend to be decided on, to some extent, unlike strategic applications (what resource is available, and then which IT application could make best use of that resource?). The results will depend not only on the value of the idea but also on the strength with which it is supported.
- As can be deduced from the methodological framework described above, decisions on investment and the priorities for the development of IT in education centers should not be made independently of the mission and objectives of the center, or only on a technical basis, but as part of a wider process. This process should also consider resources, skills, time, risks, etc., and also the correct choice of the development method to be used. In this sense, the principles underlying the classification of the application portfolio matrix are useful for selecting the development approaches. The recommendations for the four categories of the portfolio would be (Ward et al. 1990):
- *Support applications.* Largely, they consist of legally necessary applications, office applications, and personal support systems. They have value for the center, but they are not fundamental for its operation. The most appropriate solution is the purchase of a widely verified standard package that best meets the requirements of the center or that can be conveniently parameterized to fit work habits.
 - *Factory applications.* They are critical for maintaining day-to-day operations, and if they fail, the center can face serious problems. They are, generally, the workhorses, and they need to be well designed, efficient, and robust. The traditional method of development, based on the systems development life cycle (SDLC), is configured as the most appropriate in this segment. It can also be useful to buy a standard program from a recognized manufacturer, and it is essential that the application is not closed but can be parameterized in some of its functions to adapt to the needs of the center. Being applications that are important for the center, although not strategic in terms of being able to stand out in the future, completely outsourcing their development is also possible.
 - *Strategic applications.* They are vital for the future operation of the center and constitute a part of its long-term objectives. Traditional development methods are not usually appropriate in this segment, since speed and flexibility are essential, and effectiveness is more important than efficiency. The best way to develop them is through the close association between users (preferably at the level of center managers) and highly experienced IT analysts/computer programmers. The information content of the service is generally crucial in strategic systems. Therefore, easy access to relevant information is very important. In summary, for this type of application, the most appropriate form of development is the systems development life cycle (SDLC), but using computer tools to support the development itself, commonly known as CASE (computer-aided software engineering).
 - *High potential applications.* They are associated with the R&D category, where the most

innovative technology can be tested to find out its potential contribution to the center's objectives. In this case, a fast and independent development, which can be abandoned at any time, is necessary. Because the risk is high, stringent cost control is essential. The IT applications in this quadrant can be developed by a user, or by a user and a computer professional jointly, analyzing and programming the application. It is important not to risk the functioning of current systems, controlling the effectiveness of experimentation. The most appropriate development approach, in principle, is that of the prototype or the development by users, through the use of fourth- or fifth-generation languages.

Legacy Systems

Most education centers rely on legacy systems for most of their information management needs. Normally these systems offer reliable services, given that, predictably, the failures detected during their implementation were corrected years ago. The main problem with older systems is that they were developed to function in circumstances different from those of the present and have to be updated to meet current and future needs. This circumstance – the reliability of the system, but its low adaptation to new technological trends – means that it may be more profitable to make modifications to the current system than to replace it with a new one. This decision must be evaluated against the cost involved, since some older systems may be expensive to maintain or problems may arise because they operate on hardware or operating systems that no longer have technical support. These variables must be taken into consideration when reviewing the portfolio of existing systems. To summarize, if a legacy system can provide useful functionality in a cost-effective way, then it must continue to be used. In this case, it is convenient to focus this analysis on the future benefits that the system will provide, without considering the costs of the past. With this approach, continued investment in old systems is avoided, however expensive their development

and maintenance may have been, so that the anchoring effect is canceled out by the investment made. In these cases, substitution may be the only viable option for the future.

Schools and High Schools

Schools and high schools are the education centers at which the students attend compulsory education in most of the countries around the globe. Although they offer training at two different levels, primary and secondary education, they have numerous characteristics in common. That being the case, the IT infrastructure shares characteristics and objectives, being a useful tool both for the training of students and for the administrative management of the center (Gulbahar 2007). Normally, these centers do not have specific IT staff, IT support services being, in some cases, outsourced to local supplier companies and, in others, provided by centralized education authorities that serve the schools of a geographical area. At these levels, IT is not only treated as a support for teaching-learning and administrative management but also learning in the management of IT tools – mainly those related to office automation (word processors, spreadsheets, presentations) – and also for the programming of simple codes. The representation of the architecture of applications through the portfolio matrices constitutes a static photograph of a specific moment. As IT evolves continuously, the portfolio matrix also evolves as the new technology becomes ubiquitous. IT applications that are in the *high potential* cell at a given time may, after a time, enter, for example, the *support* category. For this reason, the planning process must be dynamic, and the architecture of IT applications must evolve along with the technology and the maturity of students, teachers, and administrators in the use of it.

Figure 2 shows a proposal for the positioning of the IT infrastructure in the application portfolio matrix in schools and high schools (the proposed structure is far from being normative and only aims to offer an approximation to the possible classification of the IT infrastructure through this tool). Each center can configure the location of

their applications according to their particular situation. In this way, its application architecture would be generated.

Universities and Colleges

Higher education centers have the mission of training in skills for professional and research activity. Their students are adults who choose these courses of study because of their interest in following a path toward a particular vocation. They usually present complex structures, with a large number of students, professors, administration staff, and service personnel (maintenance, security, etc.), distributed across various buildings or campuses in which different undergraduate and postgraduate courses are run and research is carried out. For this reason, it is easy to deduce that IT planning and development is a complex task that requires high levels of investment (Lin et al. 2012). Universities have their own IT support services, which can be centralized for the whole institution or decentralized across different

buildings or functional units. Regardless of the existence of an IT manager, strategic IT decisions should always be the responsibility of the rector of the university.

Figure 3 shows an example of a type of application architecture by means of a portfolio matrix for a university or college. It should be noted that due to the complexity of these types of center, the configuration can change depending on the planning and development of IT from the university level, in general, or the centers that comprise it. Therefore, it is a description by way of example that aims to reflect the different classifications that IT applications may have in this context. However, it can be observed the high degree of coincidence between the potential information architecture in a higher education center and in a compulsory education center.

Summary

Most education centers have information technology and communications infrastructure. In many

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Fig. 2 Example of an application portfolio matrix for a possible information architecture in schools and high schools

STRATEGIC	HIGH POTENTIAL
Course management systems. Electronic connection with parents.	Specific-purpose electronic devices (graphing calculators, language translators, scientific probeware, electronic thesaurus).
Student record systems. Web communication (e-learning, internet, intranet). Invoicing.	Office tools (word processing, spreadsheets). Instructional Technology (tutorials, simulations, construction kits, productivity tools, games). Management tools (budgeting, accounting, wage slips, control, schedules, etc.). Procurement.
FACTORY	SUPPORT

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Fig. 3 Example of an application portfolio matrix for a possible information architecture for universities and colleges

STRATEGIC	HIGH POTENTIAL
Course management systems. Research repositories.	Specific-purpose electronic devices (graphing calculators, language translators, scientific probeware, electronic thesaurus).
Students record systems. Web communication (e-learning, internet, intranet). Invoicing.	Office tools (word processing, spreadsheets). Instructional Technology (tutorials, simulations, productivity tools). Management tools (budgeting, accounting, etc.). Human resources tools (career development, wage slips, control, schedules, etc.). Procurement.
FACTORY	SUPPORT

cases, this has been installed to respond to particular problems related to the teaching or administration of the centers. The most common situation is that the implementation of the IT infrastructure has not obeyed any particular plan and different agents have been involved in its development, and it has often been done in different ways. IT evolves continuously and leads to the creation of new expectations by its users, which is also true in the field of education. IT has acquired a major role in education centers at all levels, mainly in administrative tasks and as support for teaching. However, the lack of long-term planning can lead to the situation whereby the IT infrastructure available in educational institutions is a burden rather than a driver of change. Within the set of functions of the current crop of education managers is to establish action plans in the field of IT infrastructure. However, the fact that a large number of education managers do not have specialized IT training, along with the limited resources usually available to educational institutions, means that IT planning and development is secondary.

In this entry, an integrating as well as a simple to operationalize framework has been proposed to guide the planning and development processes of IT in all types of education centers. It is based on a widely verified tool in the scientific literature – namely, portfolio matrices. With the proposed model, a framework is offered to guide investment decisions, priorities, and forms of IT development in centers operating at different educational levels.

Cross-References

► [Information Technology](#)

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IT on Teaching and Learning Process of Visually Impaired Students

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Synonyms

Assistive technology; Cognitive computing; E-learning; Inclusive education; Information technology; Teaching and learning process; Visual impairment

Introduction

Nowadays, technology is an essential component in our society. Considering its impact in the educational system, Information Technology (IT) cannot be dissociated from the educational process and from pedagogical practices. The role of technology is so essential in our lives today that it is necessary that students develop organizational, problem-solving, and critical skills to meet the demands of an increasingly technological work world and be fully integrated members of the society.

Since the mid-1980s, the trend has been the inclusion or inclusive education, in which the emphasis is placed on students with disabilities being included in regular education system. This inclusive model focuses on students belonging in general classrooms, and the successful inclusive education happens primarily through accepting, understanding, and attending to student's differences and diversity.

To achieve inclusion, it is necessary to be aware that all children and students have the capacity for learning and for educational development. Therefore, each school must find ways to deal with the difference, adapting teaching processes to the characteristics and conditions of each student, mobilizing the means at their disposal so that everyone learns and participates in the learning process. IT is crucial for people with disabilities and special educational needs and using them in schools to support inclusion can enable them to communicate, be included in lessons, be more autonomous, and learn more effectively (BECTA 2003).

Visual impairment (blindness, partial sight, and color blindness) is a disability category and includes the range from low vision, students who are partially sighted and can generally read print, to full blindness, the ones who are blind and cannot read print. Students with visual impairment, depending on their individual circumstances, “may not be able to rely on the sense of sight to obtain information, observe their surroundings, and learn about the world” (Presley and D’Andrea 2008, p. 4). The implications of not being able to use all visual capability can affect aspects of life and learning of students

with visual impairment. Thus, abstract reasoning and conceptual thinking are often problem areas for these students.

Visual impairment is inevitably associated with several limitations regarding electronic accessibility, but students with vision impairments cannot be excluded from technological evolution. Therefore, it is imperative that they benefit from technologies, promoting their digital inclusion, communication, autonomy, and involvement in learning.

Assistive Technology (AT) and Digital Technology

Information and communication technology (ICT) is a specific area of IT and when concerned with educational systems includes mainstream technologies, assistive technologies, media and accessible formats, educational software, and online learning environments (UNESCO 2011). Assistive technology is “software and technology which helps people with disabilities and special needs to overcome the additional challenges they face in communication and learning” (BECTA 2003, p. 3).

Technology innovations are a central factor to education. Much of the assistive technology for individuals with visual impairments has focus on accessing information (Kelly and Smith 2011); however, information technologies play several enabling roles for these students, such as enabling impairment compensation, accessing information, facilitating communication, assisting learning, arranging and sustaining support, increasing collaboration, and achieving social connection and participation (Pacheco et al. 2017). Yet, learners with visual impairment face difficulties with accessibility of websites, course learning management systems, and digital audio and video (Fichten et al. 2009b).

The first assistive technology devices were tools such as the slate and stylus, a handheld device, used to create braille. After these, manual braillewriters were developed, ensuring a faster production of texts with braille symbols, and in the early 1900s, audio technology, such as radios

and recorders, arose (Kelly and Smith 2011). With the technological development, new technologies for people with visual impairment have been developed: braille embossers, advanced close-circuit televisions (CCTVs), scanners and optical character recognition software, computer screen readers, compact discs, and many other innovations that can help people with visual impairment (Kelly and Smith 2011), such as speech synthesizers, talking book libraries, and mobility-aid solutions for mobile phones.

Nowadays, many technologies which aim to decrease the impact of visually impairment are under development. In 2017, during the Low Vision Awareness Month, the National Eye Institute, part of the USA National Institutes of Health, highlighted new technologies and tools to help the 4.1 million Americans with visual impairments; among them, the co-robotic cane, the robotic glove that finds door handles and small objects, the smartphone crosswalk app, and the CamIO (camera input-output) that provides real-time audio feedback as the user explores an object (DeMott 2017).

Students with visual impairment have also difficulty in accessing graphical materials (Butler et al. 2017). In order to overcome this barrier, students can use technologies such as sonification, haptic feedback, integrated e-book delivery on touchscreen, and three-dimensional printed tactile models (Simui et al. 2018). These technologies have been developed to help individuals with visual impairment to access graphical information, though not yet in extensive use (Simui et al. 2018).

However, and despite the wide range of technological resources, there are many barriers in receiving and using them by students with visual impairment due to internal and external factors. The lack of awareness, services, products, and financial barriers are some of the issues mentioned by researchers and international organizations (Bhatt and Kumari 2015; UNICEF and WHO 2015). Furthermore, students with visual impairment are reluctant to use these tools, once they face frustration and social embarrassment and do not want to draw attention to themselves for fear of failing to handle them properly (Bhatt and Kumari 2015).

Learning by Social Media Platforms

Besides ICT, IT also covers digital tools such as social media platforms, mobile devices, and applications, but yet, there is no empirical evidence of the role played by these last ones (Griffin-Shirley et al. 2017; Pacheco et al. 2017). Social networking services and portable devices are additional opportunities for accessing information and the preferred means of communication by students with visual impairment. These technological means are being used by these students as a complementary environment for informal and individualized learning (Pacheco et al. 2017). Computer mediates communication, both synchronous and asynchronous, and gives blind or partially sighted students the opportunity to participate actively in classroom activities, interact and communicate easily with their peers (Arrigo 2005).

Permvattana and Hollier (2013) refer that the ability to access online tutorials in YouTube, researching using Twitter, and sharing ideas using blogs conducts to benefits for education. The social network service Facebook is the most used networking service (Voykinska et al. 2016; Wu and Adamic 2014), and it is used as a communication channel, overcoming the constraints of time and space and making communication better and quicker (Pacheco et al. 2017). Wu and Adamic found that users with visual impairment “participate on Facebook (e.g. status update, comments, likes) as much as the general population, and receive more feedback (i.e., comments and likes) on average on their content” (2014, p. 3133). So, “students with vision impairments adapted social media to respond to their personal learning needs” (Pacheco et al. 2017, p. 8) and now use social media tools and applications to support online knowledge sharing and academic collaborations (Pacheco et al. 2017).

However, blind social networking services users face challenges in interacting with it due to “pervasive visual elements, complicated page structure, and infinitely scrolling feeds that are incompatible with screen readers” (Voykinska et al. 2016, p. 1593). Moreover, “the use of JavaScript to create highly dynamic web pages

can cause problems for screen readers, and bugs related to accessibility can be harder to capture and reproduce” (Wu and Adamic 2014, p. 3133). As a drawback, all these problems cannot be suppressed by the W3C Web Content Accessibility Guidelines alone, because it has guidelines to make content accessible to a wider range of people with disabilities (Buzzi et al. 2012).

Despite this, the evolution of information technology and the specific development of assistive technologies are removing barriers and enabling the same access to people with visual impairment as anyone (Wu and Adamic 2014). However, there is still much more that needs to be done to ensure universal accessibility to web content (Fichten et al. 2009a; Voykinska et al. 2016).

Learning Through E-learning

Though Internet is the main mean to access information, students with visual impairment appreciate “the fact that via ICTs they can search, retrieve and access a larger amount of information and from different sources” (Pacheco et al. 2017, p. 5). With the widespread of the Internet, it was possible to develop virtual learning environments and apply these systems in teaching and learning process. Nowadays, e-learning is becoming a valuable tool in visually impaired students’ learning process (Kharade and Peese 2012) and has the potential to facilitate inclusion of these students (Fichten et al. 2009a). Kharade and Peese define e-learning:

as the delivery of a learning, training or education programme by electronic means covering a wide set of applications and processes, such as web-based learning, computer-based learning, virtual classrooms and digital collaboration. (2012, p. 440)

The same authors consider that e-learning stimulate remote learning for students with visual impairment, enable teachers to provide remote assistance to these students, and promote continuing education for visual impaired adults. So, e-learning leads to “more effective and efficient methods for acquiring and transferring knowledge beyond the traditional classroom environments” (Buzzi et al. 2012, p. 125).

Learners with visual impairments must adapt and use e-learning, as this is one of the most used tools in postsecondary education by teachers to support the learning process (Fichten et al. 2009a). E-learning leads to the inclusion of students with visual impairments in classrooms, facilitating the access to class materials without assistance (Fichten et al. 2009a). However, Fichten et al. (2009b) observed that there is a reduced use of e-learning by teachers of learners with visual impairments in colleges and universities and they have lack of knowledge working with it.

Educational materials created for sighted students are often inappropriate for learners with visual impairments; therefore, these students with disabilities face particular challenges at an e-learning environment due to the unsuccessful support of assistive technologies and learning materials accessible issues (Fichten et al. 2009a; Permavattana and Hollier 2013). Educational materials should be provided through several means: visual, auditory, and tactile (Buzzi et al. 2012), making them accessible to everyone, including people with disabilities.

Teaching, Learning, and Information Technologies

According to Teles (2011), visual impairment is perhaps the most undervalued area concerned to information technologies and special educational needs. However, the access to appropriate technology enables learners with visual impairment to better adjust to the traditional learning processes and use of sources of information as their peers (Alves et al. 2009).

Students with visual impairment have the right to expect the same level of education just like any other students, but they face relevant difficulties in terms of accessing and using electronic learning tools and struggle to maintain the required learning pace, leading this to lower achievements (Eligi and Mwantimwa 2017; Permavattana and Hollier 2013). According to UNICEF and WHO, “the correlation between low education outcomes and having a disability is often much stronger than the correlations with other characteristics” (2015, p. 16).

Almost all education is going digital. Onukotun’s, cited by Eligi and Mwantimwa, reveals that information technologies “do not only enhance access to information but also promote education and lifelong learning” (2017, p. 88). Information technologies allow learners with visual impairment to access information and the general curriculum. They help to increase the independence of blind and partially sighted students, minimizing the deprivation of perceiving images, gestures, and colors. The use of computers, speech synthesizers, and screen magnifiers provide access and enable the production of digital information. Therefore, technologies are means to overcome the lack of vision, expanding opportunities to communicate and to develop personal autonomy; moreover, it stimulates cognitive development and enhances and leverages the appropriation of knowledge, skills, and information (Sá et al. 2007).

The speed on information processing by students with visual impairment is allowed and improved with the use of a screen reader for reading with audio support (Jackson 2012). Besides, it permits better understanding of texts, shortening the time required to complete the tasks (Jackson 2012; Pacheco et al. 2017). With the use of optical devices, research shows improvements in the students’ silent reading speeds and comprehension rates (Corn et al. 2002).

Many studies emphasize the potential of using IT in education of people with visual impairment (Bhatt and Kumari 2015; Fuglerud 2011; Jackson 2012; Kelly and Smith 2011; Pacheco et al. 2017; Papadopoulos and Goudiras 2005; Pattillo et al. 2004; Wu and Adamic 2014; Zhou et al. 2012); however, few schools and teachers implement information technologies to successfully support learning and teaching process (Nwigbo and BK 2016). In this sense and contrary to other studies, Bano et al. (2011) research shows that braille literacy, for their sample, was more important than the computer software literacy in the education of students with visual impairment, having more positive responses towards the first one. The dissatisfaction with the computer education at these students’ schools is highlighted in this research, as well as, the absence of teachers with technological required experience.

In schools, the means are not always available or suited to the real needs of students with or without special education needs (Ribeiro et al. 2010). It is crucial that schools ensure access to appropriate and necessary technology to students with visual impairment (Abner and Lahm 2002), but more importantly, suit technology to education goals and standards, and have a vision for the use of it to support the curriculum (Nwigbo and BK 2016). It is important these students with special educational needs learn to use assistive technology to access electronic information, so they can participate more equally with their sighted classmates (Presley and D'Andrea 2008).

By keeping an open mind, becoming comfortable about technology and its pervasive role in our lives, encouraging students to explore and use technology to the fullest extent possible, and promoting skills through opportunities for practice, professionals working with students who are visually impaired can help them to excel in today's competitive world – and tomorrow's as well. (Presley and D'Andrea 2008, p. 16)

IT supports new learning experiences for students with visual impairment, providing and improving this way a quality education (UNESCO 2011), a wide range of opportunities and the quality of the teaching and learning process (Fuglerud 2011). Broadly speaking, the actual challenge is to provide technological access and training (technology education) for the students with visual impairment to support learning and teaching (educational technology) (Nwigbo and BK 2016), making the best use of technology throughout their academic progression.

However, it is important to emphasize that technologies by themselves do not mediate learning but just provide influence on learning strategies, so it could not be thought as a global solution but “should be considered as a support to the learning process” (Söderberg and Fellenius 2000, p. 70).

Teachers' Role on Visually Impaired Learners' Education

Despite the increasing independency of learners with visual impairments, all teachers are prominent elements in their educational process and have an

important role to guide these students to overcome their difficulties and achieve academic success. Ramos and Andrade found on their study that teachers are aware that “ICT promote the transmission of knowledge and improve the teaching and learning process, contributing to academic success, autonomy and inclusion of students who are blind or partially sighted” (2016, p. 638).

However, many regular teachers are unprepared and fearful to deal with most of the tools and applications designed for students who are visually impaired (Ramos and Andrade 2016). This fact leads to a lower application of IT with learners with visual impairment (Ramos and Andrade 2016). Moreover, teachers are not reflecting IT on their daily classroom role due in part “to the pressures they perceived to meet their individual obligations of teaching a range of classes” (Hartnell-Young 2003, p. 2).

The use of IT by students who are visually impaired depends on the encouragement given by teachers and it is constrained by initial and continuous training acquired by those (Smith and Kelley 2007). Research indicate that teachers of learners with visual impairment do not have the necessary training on IT area (Abner and Lahm 2002; Ramos and Andrade 2016; Smith and Kelley 2007; Zhou et al. 2011); however, this lack of specific training is more severe for teachers in regular classroom than for special education teachers (Papadopoulos and Goudiras 2005). So, it is important that teachers get more training on how to work with visually impaired learners (Simui et al. 2018), as well as pedagogical support (Alves et al. 2009).

The teachers' lack of training is one of the significant problems which prevents them from achieving the full advantages of IT use in educational practices (Ribeiro et al. 2010). Teachers need time to plan, learn how to integrate technology and implement it (Nwigbo and BK 2016), thus taking advantage of their beliefs on IT potential as promoter of inclusive education (Alves et al. 2009; Ramos and Andrade 2016) and its positive impact on the curriculum (Nwigbo and BK 2016; Ramos and Andrade 2016).

With the current technological requirements and consequent application of IT at schools, it is a challenge for teachers to update and expand their

skills so that their educational activities benefit from the potential of technological resources. Although the use of IT in schools is taken seriously by governments and educational systems, “there appear to be more critical steps and vital ingredients needed for the successful infusion of ICT into educational environments” (Nwigbo and BK 2016, p. 1).

With the technological development, teachers’ role is changing, as well the traditional teaching methods have been challenged by technology-enhanced teaching and learning methods (Hämäläinen and Cattaneo 2015; Hartnell-Young 2003). According to the research findings, traditional teaching is diminishing and is arising the role of the teacher as a facilitator, guiding and coaching for students’ learning processes (Hämäläinen and Cattaneo 2015). The active role of teachers is becoming the booster to interaction processes related to learning tasks, and they are progressively working together with learners in new technology-enhanced learning contexts, such as technology-enhanced classrooms and virtual settings (Hämäläinen and Cattaneo 2015).

New Challenges to Teaching and Learning Process

IT allows students to achieve learning experiences “when and where they are needed” (Nwigbo and BK 2016, p. 5) and independency to what they learn. Besides, students making use of technology become more independent in the classroom and can discover solutions to problems both independently and collaboratively. Researches show that online interaction triggers the opportunity to share information from their peers (Pacheco et al. 2017). Therefore, IT promotes the cooperation and collaboration among learners within and beyond school, having a positive effect on teaching and learning process, “introducing news and better ways of learning and teaching” (Nwigbo and BK 2016, p. 6). Technology can support new types of learning possibilities (Hämäläinen and Cattaneo 2015), as well as promote students as active learners and with the desire of discovery and knowledge.

In education field, based on each individual student’s needs, cognitive computing services – data-driven artificial intelligence (AI) – provide content, planning, and intelligent activities to promote knowledge in an effective and personalized way. In fact, according to Coccoli, Maresca, and Stanganelli, “from the e-learning point of view [...], cognitive computing can be an accelerator for students’ achievements, and a valuable support for the teachers” (2016, p. 62).

Cognitive computing can either support teachers in solving common students’ issues, such as “school dropout, individualization of learning, customization of training path, etc., due to their capability of analysing data” (Coccoli et al. 2016, p.64). Teachers can adopt new tools of cognitive computing to conduct individualized experiences and provide a “range of activities to assist students to become critical thinkers, designers and problem solvers” (Nwigbo and BK 2016, p. 5).

Recently, several tools and platforms based on cognitive computing were created: Cognitive Reasoning Platform by Enterra; Deep Learning, by Microsoft; DeepMind, by Google; IDOL, delivered by HP; and Watson, by IBM. Digital interactions with students, promoted by these platforms, can enhance learners’ performances and help educators personalize and adapt their approaches to students’ results (Coccoli et al. 2016). To drive personalized teaching, IBM Watson Education offers teachers a new level of engagement and a detailed view of each student, including achievement, academic performance, attendance, behavior, and activities learned.

The mobile app market is growing, and it is providing accessible experiences for visually impaired smartphone users. Microsoft has released, on July 2017, the new free artificial intelligence application for Apple’s iPhone, called Seeing AI (formally known as Deep Vision), designed for the low-vision community. This app uses mobile camera and describes people, text, currency, color, and objects that are being photographed. This app can turn the visual world into an audible experience (Microsoft n.d.) and can be applied in educational context to overcome visual barriers faced by these learners.

Artificial intelligence can make the educational experience more effective and engaging, both for

students and teachers and “the current absence of sophisticated use of AI Technologies in schools, colleges, and universities may be explained by the lack of financial resources as well as the lack of data establishing the technologies’ effectiveness” (Stone et al. 2016, p. 33).

Virtual assistants, sometimes called smart speakers, from Amazon, Apple, Google, and Microsoft, such as Alexa, Siri, Google’s Assistant, and Cortana, respectively, are voice command platforms which can carry out a range of tasks. Therefore, applying these platforms in schools, students can interact with them and get real-time personal feedback. These can be useful in schools unlocking barriers for both students and teachers and a source of information and enhancing thought-provoking tasks. For example, these platforms can be used by learners with visual impairment to find library materials faster.

The arise of digital voice assistants in education is inevitable, so it is important that educational system explore how can it create more effective, engaging, and creative learning environment.

“New competencies are required by teachers of pupils with visual impairments in mainstream schools,” opposing these “from the traditional model of training dating from the time of the special school and the ‘sight class’ era” (Söderberg and Fellenius 2000, p. 69). To achieve the real potential of IT as well as the important educational goals of students with visual impairment, it is essential that educators use IT in learning situations (Alves et al. 2009; Presley and D’Andrea 2008).

Conclusions

From the viewpoint of the implementation of IT in visually and partially sighted students teaching and learning process, research studies indicate that IT enables students to overcome barriers of learning, as well as develop their inclusion in the mainstream classrooms. Applying them to support education can lead to educational benefits such as improving learning and increasing communication skills, yet, not all students have positive feelings towards IT daily educational use.

Thereby the continuous development of IT, its implementation, for educational purposes, with students with visual special needs, has a long way to go. Educational community must be open-minded to exceed the traditional teaching model and place greater emphasis on the active role of students with visual impairment inside and outside classroom, using the available technological means, even those which are behind educators’ comfort zone.

Even when technology is available, access may still be problematic. To avoid insecurity and frustration by students with visual impairment, dealing with accessible web issues, it is important to ensure full accessibility of the learning environment and the educational materials, following the W3C guidelines.

Therefore, material conditions of the schools should be strengthened, and a greater commitment must be done by the educational community, especially by teachers, to implement IT in learning and teaching process. Teachers refer barriers to the low use of technologies as a mean to optimize the learning process, such as time constraints; insufficient knowledge to adapt technological means to visually impaired learners’ needs, reinforced with the deficiency of training on this specific technological area.

They can maximize the impact of IT on teaching and learning process by understanding the potential of it to support students with visual impairment and tailoring and adapting activities to involve these students in learning. Online discussion forums can be used to access information, advice, and guidance, as well as to share knowledge and for reflection among teachers in regular classroom and special education teachers. It is utterly important that all community get involved in this process.

Cross-References

- ▶ [Assisting People with Vision Impairments Through Technology](#)
- ▶ [Assistive Technology and Inclusion, Philosophical Foundation](#)
- ▶ [ICT-Based Inclusive Education](#)
- ▶ [Teacher Education, Thinking About ICT](#)

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IT/ICT in Mathematics Teaching and Learning

► Technologies in Mathematics Education

J

Java

- ▶ [Applying Software Engineering Principles in Android Development](#)
- ▶ [Programming Languages for University Courses](#)

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- ▶ [Assisting Students with Learning Disabilities Through Technology](#)

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- [Programming Misconceptions at the K-12 Level](#)

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Knowledge Economy of Faculty Competencies of Indian Business School

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Synonyms

[Business School-India](#); [Faculty research competency framework](#); [Knowledge management](#); [Modelling technique exploratory factor analysis](#)

Introduction

It is believed that the business schools are driven by its traditional role of teaching from text books based on syllabus that is outdated (Schurman and Louis [2010](#)). The educational system must fulfill the need to create lifelong learners geared

to “add-value” in the knowledge-based economy (Bailie 2011). In fact, worldwide, the business schools are struggling hard to maintain their faculty brand. The faculty research output and efforts have also been criticized of late, with some business practitioners arguing that academic research is irrelevant (Bennis and Toole 2005). It is believed by the researchers today that research-based business education is a necessity for improving business practices. The roles of faculty increased from teaching to do research; from researchers to case writers; and from consultants to mentors. Furthermore, Indian business school faculty members actively participate in various administrative positions from time to time. This raises an important argument of how they will succeed in maintaining quality of competent faculty, particularly in research but also other competencies described above. The brand value of a business school may involve the brand value of faculty. Important factors like personality, ability, knowledge, and skills play an active role in determining the competencies of the faculty. They are required to generate skills to sustain in the world of collaborative alliances between business schools and industry (Ranjan and Tripathi 2010). Also, research output is valued in a knowledge economy.

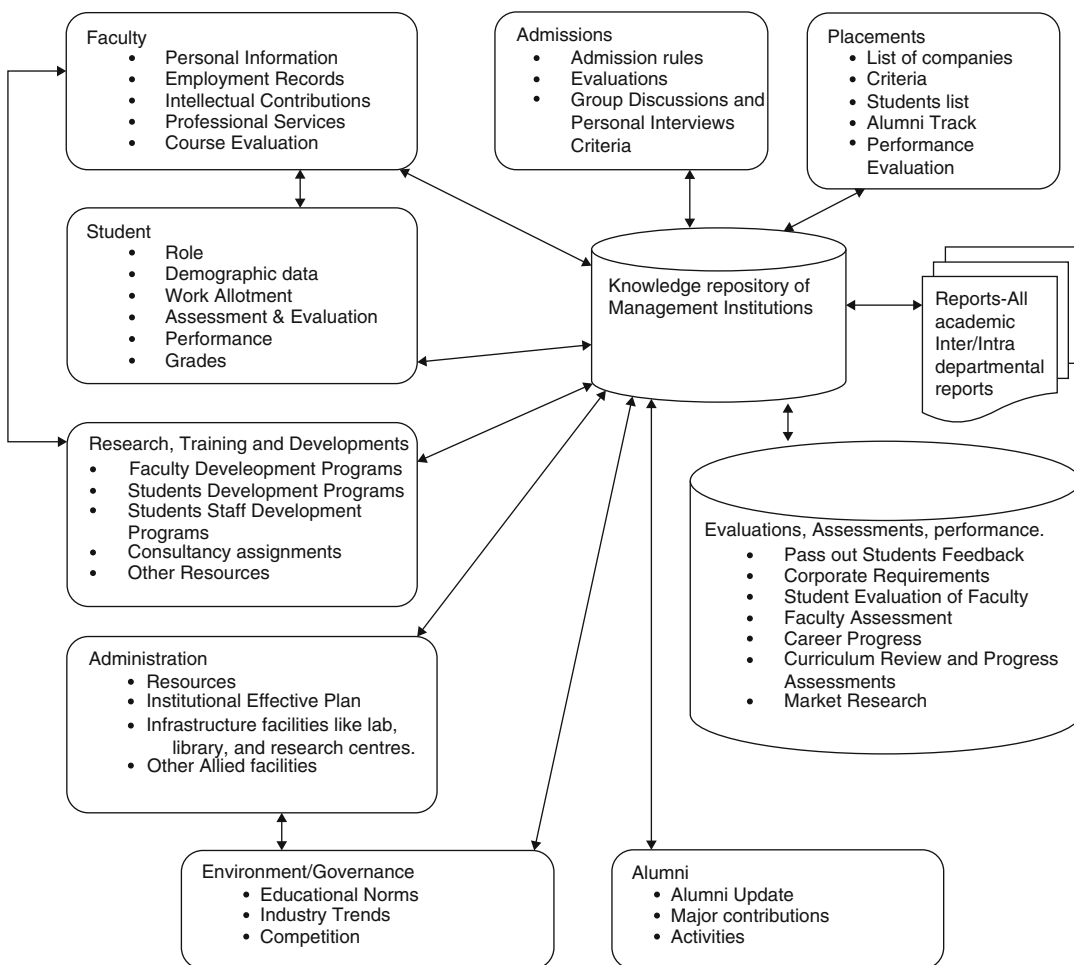
The faculty members take enormous challenges, in terms of contents and web-based technologies, to understand and implement research teaching into integrated educational practices (Mason 2003; Hramiak 2005; Bailie 2011). They pursue scholarly academic research sometimes even in the absence of explicit financial returns, according to existing empirical evidence. There is literature that suggests that research and economic value creation for students are at least correlated (Friga et al. 2003; Mitra and Golder 2008; Rindova et al. 2005). Although the correlation may seem to be spurious but in reality, any BSF research activity not only results in student value creation but also directly impacts the ranking and image of the business school. The teaching paradigm for faculty to help students in finding place and purpose is very important (Chambers 2002). From the administration’s point of view, there is also a need for creating a bridge to the future by preparing faculty to face new challenges (Austin 2002).

Chambers (2002) analyzed the teaching paradigm for the development of faculty to help students in finding place and purpose. Austin 2002 identified the need for creating the bridge to the future by preparing new faculty to face changing expectation in shifting. Braskamp (2000) studied a holistic approach to assess faculty. Draganidis et al. (2006) implemented an ontology-based application that can be used for competency management. There were many related studies (Ranjan and Tripathi 2007a, 2008, 2010; Tripathi and Ranjan 2011, 2013) that dealt with some aspects of competency management in India for various educational institutions. This study extends the perspective to business school faculty.

Business School Faculty Competencies (BSFC)

The BSFC framework includes (1) obtaining competencies of faculty (2) understanding faculty roles and making a theoretical foundation (3) obtaining factors (6) validation and discussion. Exploratory research was being conducted to understand the significance of faculty competency management system and its underlying factors. In order to identify prototypical faculty dimensions, conducted qualitative research. Focus group discussions were held with academicians, and various educational consultants, and management consultants in education from different educational institutions and organizations. As a result, obtained a list of 16 variables that can influence a BSF. These elements were the basis for identifying competency-based management (CBM) process and quality in business schools. For an integrated view of an effective framework for the CBM, refer Fig. 1.

Business school faculty competency (BSFC) on the lines of Wrzesniewski and Dutton (2001), who defined job crafting, as the physical and cognitive changes individuals make in the task or relational boundaries of their work. Thus, it studied in this work how, when, and why BSF are likely to craft their jobs and roles, and how this will have impact on their identities and work meanings. For this



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Knowledge Economy of Faculty Competencies of Indian Business School, Fig. 1 Competency-based management framework. (Adapted from Ranjan and Tripathi (2009))

purpose, assumed the principles of Fayol (2001) and designed 16 roles for faculty.

Competency-Based Management Framework Adapted

Motivation to craft a competency is more likely to spark crafting of competencies as faculty perceive that opportunities for competencies exist. Perceived opportunity to craft a competency refers to the sense of freedom or discretion faculty have in what they do in their competency and how they do it. Like other opportunity perceptions, opportunities to craft competency are psychologically

positive, since they imply a form of control, a sense of possible gain, and some sense of ability or means to act as described for employees and jobs by Jackson and Dutton (1988) and Lazarus and Folkman (1984). Thus, motivated faculty are likely to assess opportunities for all competency crafting at work before crafting their competencies.

The CBM model that defined in Fig. 1 sets forth the basic contribution to the type of competency roles that one business school faculty need to have, both of which are tied to the actual design of their work: (1) the level and form of task interdependence and (2) the level of discretion or freedom to craft competency, based on monitoring systems in the competency.

In any business school, faculty work with more or less task interdependence built into their work. This faculty competency is similar to the task defined by that states the extent to which the items or elements upon which work is performed so that changes in the state of one element affect the state of the others. Faculty engaged in competencies with higher degrees of interdependence are yoked more strongly to the timing and competencies of others, restricting the degree of possible task alterations, how the faculty perform using their competencies, and with whom they interact along the way. Thus, those with more task interdependence work under more constraints and have less freedom to alter task and relational boundaries as a result.

For example, a faculty who is bound to have institutional administration as competency cannot bring drastic changes and is constrained to work under limitations. Whereas a faculty whose competency is teaching, instructing, or researching is free to experiment with different methods of innovation. When faculty have many competencies like ability to be a good teacher, very good researcher, or to bring consulting opportunities, to communicate well with their peers and colleagues and students, such “super faculty” may perceive other competencies to be least important. The study argues that when faculty’ competency are explicitly defined and controlled, faculty may see more opportunity for crafting activities. This contradicts the job crafting model defined by changing any one of the roles the BSF can alter the design of the job and the social environment in which he or she works. By BSFC means how individuals define themselves at school similar to “work identity” defined by Wrzesniewski and Dutton (2001). As indicated by Ashforth and Mael (1989), while such identities cannot be changed at will, faculty may claim to have them and also why such a competency matters in the business school work place. Work identification, like business school identification, assumes correspondence between how individuals define themselves and how they define their work (Pratt 1998). When faculty interact, what role they play and which role makes them more effective is important. For example, if a faculty goes from

one role to another, say from alumni chairperson to research chairperson, then the meaning of the job and the identity and role change as well. IT believe changing roles have huge effect on the faculty competencies, though have not measured it the effectiveness of each change in each role in this study. The study identified the necessary roles for a faculty which drives the value of their competency.

The defined competencies for BSF if utilized effectively would lead to enhanced meaning in the work and BSF in fact would feel responsible. These competencies should be the prime parameter for faculty appraisals and promotions. The assert autonomy in the competency leads to perceived opportunities for BSF and encourages faculty to alter the task and relational boundaries of their competencies. This argument suggests that there are contradictory forces at play in the modern workplace that might affect competency crafting patterns. In Table 1, presents 16 roles of BSF competencies.

Managerial Implications of Business School Faculty(BSF)

The model competency identification for BSF offers significant contribution on how business schools think about and study their BSF. With the model of CBM, contributes to theories of BSF design by offering a new perspective on how competencies are constituted. The results specified the motivations, job, and individual features that create situations making CBM for BSF possible. The process proposed opens up different pathways for understanding how people channel their competencies and effectively shows that BSF can be competent designers of their work. This means BSF are more argentic than typically depicted in theories of job design. Rather than paint BSF as passive recipients of job tasks or of social information about job tasks, the CBM model indicates that BSF need to define their CBM roles for their jobs and use the feedback from these definitions to further motivate their CBM.

BSF competency and the roles are neither inherently good nor bad for business schools.

Knowledge Economy of Faculty Competencies of Indian Business School, Table 1 Faculty roles and their competencies

S. No.	Faculty roles	Brief description of faculty roles
1	Administrator/leader	Understanding the various administrative tasks that are associated with the implementation of education, training, and development activities. Need to provide the role of director, dean, chairperson, leadership, guidance for projects, alliances, partnerships, act as a chairperson to any academic domain. For example, chairperson of international relations, alumni committee, students affair council, research, etc.
2	Consultant	Faculty role as a consultant pulls more opportunity for industry institution interaction. It promotes more research opportunities Faculty role as a consultant brings more value to the classroom All faculty need to display academic excellence in classes. He/she has to undertake consultancy assignments and work towards bringing/engaging students using standard industry practices to IT companies, area-specific companies
3	Problem solver	Seeing organizations as dynamic, political, economic, and social systems which have multiple goals, using this larger perspective as a framework for understanding and influencing events and change. Faculty effectively organizing workshops, seminars, and conclaves and educating issues
4	Teacher	A faculty constantly needs to update himself/herself by attending various advanced educational programs like postdoctoral training programs, keeping abreast of new information and hence sharing the same with students. With primary objective of knowledge dissemination and knowledge sharing
5	Executor	All business school faculty need to display leadership skills in the sense while taking class, organizing events, in bringing training programs to institutions, in discussions and debates, one has to display enormous amount of leadership skills. All administrators may not be leaders. But all leaders have to display administrative skills. All administrators can be leaders if they hold a particular positions and need to maintain a high degree of professional leadership qualities
6	Mentor	The role of business school faculty will not be complete if he/she does not mentor students in nurturing and shaping in good direction
7	Editor/reviewer	For any business school faculty becoming a editorial member, editor or associated as reviewers to any good refereed journals in the world is a proud moment; it not only yields heavy networking contacts but it also promote up to date knowledge of processes, both industry and institutional developments in the world Faculty roles in editing, reviewing journals adds value to the development of action-based research; this exposes to world's different views of studies on the various issues of management
8	Researcher	Selecting, developing, and using methodologies, statistical and data collection techniques for a formal inquiry. This promoted action-based research outcome for both industry and institute
9	Team player	Knowing what factors inhibits team effectiveness and what can be done to promote teamwork. In business schools, all processes usually are done with teams from different teams. One has to be a good team player to imbibe the vision and mission of each team's objective
10	Executor	Each task provided by a business school to faculty are mostly tasks oriented, the faculty has to perfectly execute. Here the faculty need to display strong common sense and more timely inputs. He/she has to be a good executor
11	Planner	The faculty need to plan almost every operation he or she associated with. She has to plan the course, teaching methods, training programs, etc. Here all the planning methods that a faculty prepares need to be innovative, industry-based action research oriented, more creative, and she needs to deliver the same after planning. Else planning does not have any meaning if it does not delivered or executed
12	Evaluator	The faculty need to be a true evaluator of all processes like research outcomes, project outcomes, internship methods, alumni relational outcomes, placement processes, corporate linkages, student project evaluations, etc.

(continued)

Knowledge Economy of Faculty Competencies of Indian Business School, Table 1 (continued)

S. No.	Faculty roles	Brief description of faculty roles
13	Examiner	The faculty role as examiner is very crucial in the sense he/she needs to invigilate in exams, assess the performance, and examine the quality of student performance wise as well as behavior wise. She/he has to examine several proposals (for example, related to alliances and partnerships, training, and development)
14	Facilitator	Planning and coordinating logistics in an efficient and cost-effective manner. His facilitations as tutor, evaluator, and as such all the roles mentioned, he/she must do that maturely
15	Instructor	The business school faculty's primary role is an instructor. Teaching and research originate from this. When the faculty starts teaching, research ideas develop. The instruction methods that he/she uses
16	Communicator	The faculty need to bridge the gap between teaching and learning; for this, he needs to be an effective communicator. For complex educational problems, the faculty has to inspire

The degree to which BSF competency contribute to school branding, performance depends on the kinds of changes BSF make and on their roles. In this study suggested that BSF competency and their roles are one route by which BSF alter the meaning of work and forge new identities. If these meanings and identity constructions motivated behaviors that aligned individual work patterns of BSF, then BSF's CBM could be a net positive for any business school. However, if BSF competency altered connections to others or task boundaries in ways that were at odds with school objectives, then BSF competency might harm rather than enhance school effectiveness. BSF competency effects on schools that are also dependent on the systems in which individuals work.

To produce global leader, the mission of BSF is to provide students with the right mental and technical skills that are needed for their lifetime careers in business administration. Here BSF plays a very important role. In India, every business school generates information about students, courses, faculty and staff that includes managerial systems, organizational personnel, lecture details, quality research, and so on. This useful information, which serves as a strategic input, is very useful in improving the quality of the teaching of the faculty member and thus the quality educational process. BSF competency should be envisaged to be a special breed. A qualified BSF understands business situations and can correctly incorporate them into the learning process.

Without an effective way to brand the business school information collected, information about BSF often go underutilized. Parts of a collection can remain untapped for years, and the larger it grows, the more difficult its management becomes. Unfortunately, improving this usually comes at a cost – at a time when budget cuts have forced most of the faculty either quit or develop in-house research without exploring industry requirements. Each time the senior management and leadership change, it would have an adverse impact on faculty performance and roles. Lifelong learning, according to Aspin and Chapman (2001), is concerned with promoting skills and competences necessary for developing general capabilities and specific performance in work situations. This is just right for faculty skills and competences, as lifelong learning is vital for faculty performance in their tackling of precise job responsibilities and how well they can adapt their general and particular knowledge and competences to new tasks (Aspin and Chapman 2001).

In India, around 3500 business schools generate information about students, courses, faculty and staff that includes managerial systems, organizational personnel, lecture details, quality research, and so on. The BSF's CBM unfortunately are not focused. The authors emphasize that the developed framework would only serve as a reference or self-checking mechanism and would not bring a "miraculous change or transformation" in business schools. Setting up faculty

competency target parameters and awarding and rewarding faculty may not lead to faculty research outcomes, but if combined with clear documentation, consistent performance may well be a step in that direction, particularly if the system is aligned with mission and vision of the institute.

Competency Management for BSF

The competency of BSF can be accessed through knowledge behavior, administrative skills, institutional development activities, and research contributions. The roles of BSF in Table 1. Based on these roles, evaluate the faculty competencies. One may fulfill the knowledge criteria by satisfying the relevant subject knowledge and getting a great feedback received from students, but the faculty may lack in other competencies such as research, consultancy, institutional development activities, etc. Table 1 defines the roles and responsibilities of the faculty members developed by the authors.

The key is the ability to integrate BSF data efficiently and produce world class research and teaching standards that assist the B-schools in achieving its goals and ranks. This is important and essential for showing various government domains, accrediting bodies and other stakeholders who require periodic reports on the overall progress of their schools.

Conclusion

In business schools, there are many diverse heterogeneous faculty data is available. Faculty performance and their contribution drive any good business school. They don many different roles for the sustainable success of business school performance. The competencies can play a major role in examining and enhancing the effectiveness of business school faculty. The competence management performance assessment process of teaching and learning process is the biggest generator of information and knowledge as well in business school. It is clear that recognition of high

quality educational research by professors is dealt for students' admissions every year. The business schools have been making substantial investments for their faculty development programs to promote faculty roles. The regulatory bodies, accreditation bodies are seeking more information to measure and evaluate the effectiveness of the faculty.

Cross-References

- ▶ [Competency Models in Computing Education](#)
- ▶ [Data Mining for Educational Management](#)
- ▶ [Modeling the Process of Information Technology Innovation in Education](#)
- ▶ [Situative Perspective and Determinants of Technology Acceptance in Educational Technology](#)

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Knowledge Gap Theory

► Literacy and Technology

Knowledge Management

► Knowledge Economy of Faculty Competencies of Indian Business School

Leadership on Information Technology in Education

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Introduction

Since the beginning of the twenty-first century, many countries worldwide have been undergoing major social, cultural, and economic developments. In the process, these countries have come to realize that for sustainable economic development, relying mainly on natural resources is insufficient; what are needed, in addition, are “investments in knowledge that can facilitate technological innovation” (Tseng 2014 as cited in Abdul Razzak 2018). Consequently, we find many societies and economies shifting direction toward becoming knowledge and information-based, respectively.

A knowledge-based economy is an advanced economy in which there is greater reliance on information and high skill levels (OECD 2005); while, an information-based society is a society that relies on gaining competitive advantage internationally through major dependence on and use of data, information, knowledge, and Information Communication Technology (ICT) in creative and productive ways. (Abd.Mukti and Abd.Malik 2004; Abdul Razzak 2014, p. 62)

What this indicates is that currently economies are strongly and substantially correlated with ICT integration in every aspect of life (Abdul Razzak 2013), particularly in the field of education and training, in which the development of human skills and competencies required for preparing citizens for tomorrow’s workforce and employment challenges takes place (Abdul Razzak 2018).

ICT integration in education is also known as educational or instructional technology, and as a concept, it has been historically considered ambiguous to define; for its definition depends mainly on how the concept gets interpreted. Nevertheless, having a clear definition of the concept of educational technology and a description of what, as a practice, it entails is imperative for understanding a related important aspect currently found in almost every educational institution, namely that of technology leadership in education (Puckett 2014).

Technology leadership, as a fairly new style of leadership, has now become a necessity in educational institutions, since technological developments of this information age, along with the entry of digital technologies into educational institutions, have noticeably impacted educational systems in general, and teaching and learning processes in particular (Yorulmaz and Can 2016; Flanagan and Jacobsen 2003). This has in turn led to significant changes in the roles and responsibilities of teachers and administrators alike; as, they now find themselves in a position where they are

faced with the huge task of reshaping their educational organizations and practices in ways that better meet the needs of their societies, which have been considerably transformed by the new information age and the digital technologies that form it. The current roles and responsibilities of those in education now, therefore, require technological literacy on their part and include a widespread integration of ICT in almost every form of activity carried out in their institutions. Having a clear understanding of ICT integration in education is therefore crucial to them and to anyone interested in the topic, for that matter, especially when various interpretations of the concept exist in the literature and are in use in practice, and where some of those interpretations are more clear-cut than others.

Some interpretations of ICT integration in education have been simple and limited while others have been more complex and broad (Lakhana 2014). The simplest of interpretations restricts educational technology to applications of hard technology for the purpose of addressing problems in education. What hard technology refers to is mechanical and material tools, especially computers and computer programs. This limited interpretation of educational technology is problematic since it overlooks the human side and the reciprocity that exists between technology and the human intellect (Lakhana 2014). In other words, it fails to take intellectual and social significance into consideration, which usually focuses on the organization of knowledge for the achievement of practical purposes that assist human adaptation to, and participation in, the environment – and all this is done simultaneously through interrelationships with particular social values (Luppigini 2005). Nevertheless, this limited interpretation of educational technology dominates contemporary discussions and literature including governmental publications, in the form of an emphasis on the hardware, software, and tools utilized in the field (Lakhana 2014). The adoption of such an interpretation by any social scientist is something, obviously, farfetched for the simple reason of education being all about human constructs and social interactions. Besides, it is not possible to discuss or research any educational technology

issue without several cross-disciplinary views coming together (e.g., pedagogy, computer science, media technology, theory of knowledge, psychology, ethics, and quality assurance), among which many belong to the sphere of the social sciences (Balter 2017). This explains why more complex and broader interpretations of the concept exist, which usually consider educational technology as also including, in addition to hard technology, soft technology in the form of “immaterial tools, such as processes and ways of thinking” and address “the causal interdependence between intellectual growth and technological growth, whereby technology is not merely processes and tools, but is understood systemically” (Lakhana 2014, p. 2). These broader interpretations of the concept have over time led to evolving definitions of educational technology reflecting a history of social and technological change, whereby different definitions reflect different generations in time (Lakhana 2014). What this therefore signifies is a dynamic definition of educational technology that changes with the times rather than a static one, and this possibly explains why till now no universal definition of the concept exists. Despite this, however, various definitions of more or less the same flavor are widespread in the literature and are practically in use; some of these definitions are presented below.

Information Technology in Education

Definition of *Educational Technology*

As explained above, there are various definitions of *Educational Technology*; for example, the Association for Educational Communications and Technology (AECT) defines it as “the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources” (2004, p. 1); whereas, the International Society of Technology Education (ISTE) defines it as “Devices, apps, webs, resources, internet access, technology support and other digital tools used to deepen learning.” Similarly, comparable definitions have been provided by many scholars and researchers, such as the definition of Spector (2012), which considers

educational technology as involving an application of knowledge that is orderly and well-organized, intended for the purpose of improving teaching, learning, and performance; or the definition of Brown (2014), which emphasizes the use of technology tools like SMART boards, electronic whiteboards, computers, videos, the Internet, BYOD (Bring Your Own Device), blogs, and social networking, to enhance student learning outcomes. A more comprehensive definition is provided by The George Lucas Educational Foundation: Edutopia (2007), which describes educational technology as “the use of technology resources in daily classroom practices and in the management of the school; it is achieved when the use of the technology is done routinely and in a transparent way and when technology is readily available and accessible to everyone in the school, supports the curricular goals, and helps students effectively learn and reach the 21st Century goals set for them” (cited by Abdul Razzak 2014, p. 61). Abdul Razzak (2013) builds on this definition by adding that educational technology involves three main components: (1) teachers and students learning how to use ICT, (2) teaching using ICT, and (3) students learning with and through ICT, which paves the way for the discussion of the necessary conditions needed for effective ICT integration in education; since, without these three components being in place, such integration would not be appropriate and may result in negative by-products (Abdul Razzak 2014; Flanagan and Jacobsen 2003).

Conditions for Effective Educational Technology

Although having a good technological infrastructure in an educational institution is necessary, research studies emphasize that it is not at all sufficient for effective ICT integration in education (Sadera 1997; Flanagan and Jacobsen 2003). Rather, many other conditions need to be met for ICT in education to be successfully implemented, among them: teachers and school administrators adopting a positive attitude toward such integration; believing in the usefulness of ICT in education; being provided with the suitable training for it; possessing relevant pedagogical and technological knowledge; being willing to abandon old

pedagogies, teaching methods, and ways of doing things; having sufficient confidence to try out innovations and take risks; and being provided with sufficient support (Abdul Razzak 2013). In fact, many researchers have suggested head-teachers’ or leadership preparation as being the most significant element in, and the best predictor of, the success of ICT integration in teaching and learning (Afshari et al. 2009; Kor et al. 2016). This is because technology integration is about change and involves a type of re-culturing, so that teaching and learning with ICT is accepted and actually adopted. In addition, every attempt of ICT integration in education presents a special case of change, since it usually takes place within a specific context that happens to have its individual peculiarities and challenges, and thus needs to be understood and carefully managed based on its own uniqueness. Accordingly, this calls for an astute and strong leadership that can ensure the smooth implementation of change and assist in overcoming any challenges (usually referred to as “barriers” in the literature) that are normally known to come along with implementing ICT integration (Abdul Razzak 2013). The question that poses itself here relates to the type or style of educational leadership that would best match the profile of a strong leadership for ICT integration in education. Before reaching an answer to this question, however, an explanation of leadership in education, including an exploration of the different educational leadership styles or models, is necessary.

Leadership in Education

Definition and Models of Educational Leadership

At its simplest, leadership can be defined as “a process whereby one individual influences a group of individuals to achieve a common goal (Northouse 2001)” (as cited in Seyal 2015, p. 32). What constitutes effective leadership, however, may differ from context to context (Bradley et al. 2017). In the realm of education, whether in a school or in a higher education institution (HEI), leadership is known as academic or educational leadership. At the school level, the principal or head-teacher is commonly thought of as the

educational leader; although, leadership is not confined to the principal, since even senior teachers (also called department heads) and classroom teachers are considered as educational leaders, or better yet as exhibitors of teacher/instructional leadership, when they clearly demonstrate leadership qualities or appear as champions in a particular area of competence. At the level of HEIs, things are a bit more complicated, not only because of the different structural levels that can exist within an institution (e.g., committee, department, college, university level) but also because of the multiplicity of administrative positions and academic ranks that can be in many cases intertwined. This makes it more difficult to specify who the educational leader/s in such a context usually is/are. In any case, educational leadership can be defined as “the distributed practice of carrying out the institution’s strategic vision while supporting the development of intellectual authority and a shared identity that fosters collegiality” (Bradley et al. 2017, p. 100). Since this definition encompasses vision as a core concept, then it emphasizes the pursuit of a better future for the whole organization, rather than merely stressing successful management of day-to-day activities, as formal *managerial educational leadership models* tend to do. In addition, by incorporating the ideas of distributed practice and a shared identity, this definition seems to extend from a collective model of educational leadership, in particular *the distributed leadership model*, which focuses on power sharing between staff members in the organization, who work collaboratively together in a trusting atmosphere, accepting to lead in their areas of expertise, and reach decisions together based on discussions, agreements, and consensus (Bush 2011). For this reason, this style of leadership is sometimes referred to as “the government of the many” (Lumby 2012), though without necessarily implying a reduction in the scope of the principal’s or senior administrator’s role (Bush 2011). Based on the definition provided, therefore, an educational leader’s role is to promote a shared identity that helps in sustaining the institution’s culture, core values, and goals that are aligned with its strategic vision, while at the same time leaving room within

it for intellectual freedom and individual and collaborative growth. Since educational leaders have to work with both administrative and academic staff and since they face a challenge of trying to strike a balance between administering resources, on the one hand, and promoting intellectual authority and the pursuit of scholarly goals on the other, then there is evidence that shared or distributed leadership may be a good fit for academic institutions (Bradley et al. 2017). This is because, through it, administrative tasks can be assigned to the nonteaching staff, while academic tasks and duties can be left in the hands of the academics to lead. This way, academics can be given more room to effectively focus on and set the direction for the job they were originally hired to do, whether in terms of teaching or research, without having to worry about bureaucratic demands that usually exist in the system (Bradley et al. 2017). For this reason, the distributed leadership model with the definitions of educational leadership that spring from it have been quite popular among scholars of the twenty-first century. Lumby (2012), nonetheless, admits that although distributed leadership is apparently suitable for the education sector, it is not common in educational institutions, which in practice tend to adopt more of a blended leadership approach that mixes between management and the efficient use of resources, on the one hand, and leadership on the other.

Other more classical educational leadership models are *the transactional* and *the transformational*. In transactional leadership, the focus is on gaining compliance of those in the organization through a system of motivation based on the exchange of rewards for the services they provide. This type of leadership therefore focuses on a contractual process of give and take, where the leader takes from the followers what is needed and gives them in return what they want. As long as the leaders’ needs are in accord with the followers’ wants, harmony prevails in the organization. Bush (2011) considers this type of leadership as more relevant to a political model of educational management, and Seyal (2015) views it as a leadership style more suited to stable work environments with little competition, which the

current changing educational environments of the information age are very far away from.

Standing in sharp contrast to the transactional model is *transformational leadership*, which along with *instructional leadership*, are seen by some researchers as having been playing the lead role in technology integration since 1990 (Hallinger 2007, as cited in Seyal 2015 p. 39). The transformational leaders, according to Yukl (1998) (as cited in Seyal 2015, p. 35), define the needs for change, create new visions, and work on acquiring their followers' commitment to the organization's vision and objectives through developing their self-motivation; coaching and empowering them; and inspiring them to transcend their self-interests and pursue instead higher-order goals aligned with the organization's set direction. In their actions, transformational leaders, therefore, are characterized by inspired motivation or charisma, individualized consideration, and intellectual stimulation; they use emotions to encourage staff to pursue the articulated shared goals, show personal interest in and provide support for employees and their development, and encourage innovative thinking and foster creativity and rational problem-solving (Bass 1985 as cited in Seyal 2015, p. 34). One more dimension of transformational leadership is idealized behavior, which relates to acting and integrity. What this refers to is that transformational leaders believe in, and demonstrate, self-control, high moral judgement, optimism, and self-efficacy. "They are strong believers of moral and ethical consequences of their actions" (Seyal 2015, p. 39). This idealized behavior on the part of the transformational leaders is what makes their followers respect and trust in their vision, especially in times of change and adoption of something new (Seyal 2015), such as a new technology tool or practice – just like what takes place in the process of integrating technology for teaching and learning purposes. For this reason, researchers (e.g., Daughtry and Finch 1997; Schepers et al. 2005; Seyal 2007) have concluded that transformational leadership style is a good fit for ICT integration in education; their study results collectively indicated that such a type of leadership is capable of promoting a culture of technological

innovation, of positively influencing perceived usefulness of technology, and of effectively facing challenges of technology (Seyal 2015, p. 35). Not only that, transformational leadership is capable also of moving others toward accomplishing more than what is usually expected of them (Northouse 2010 as cited in Seyal 2015). Still, however, a word of caution is needed here; despite the attractiveness of this type of leadership model, it is not totally free of limitations. For, as Bush (2011) warns, "it may be used as a vehicle for the manipulation or control of teachers who are required to support the 'vision' and aims of the leader" (p. 202).

Like the transformational style, instructional leadership is also considered as suitable for educational technology, primarily due to its focus on the prime purpose of educational institutions, which is teaching and learning (Bush 2011). Instructional leaders, therefore, allocate most of their scheduled time to activities that have a direct impact on student achievement, such as: curriculum coordination, selection of instructional materials, and professional development planning – all of which can involve ICT integration in them if necessary. The role of the instructional leader is not limited to the principal or senior administrator, since it extends also to other key players in the educational institution such as assistant principals, curriculum coordinators, or senior teachers. Despite this model's endorsement by the English National College, however, Bush (2011) explains that it has two main weaknesses, namely: (1) it tends to underestimate and turn attention away from a number of educational purposes and aspects, including student welfare, socialization, and the development of the young into responsible adults and (2) it is limited since it does not explain much about how exactly instructional leadership is to be developed.

With this exploration of a few of the most dominant educational leadership models in the literature, the question about the most suitable leadership style for ICT implementation in education persists. Since, it is obvious, as Bush (2011) explains, that it is rare for any one single model among these models and others like them to capture the reality of leadership within one particular

context or institution. Instead, it is more common to see “aspects of several perspectives present in different proportions within each institution,” with the applicability of each perspective or model varying with the event, situation, or the participants (p. 205). For this reason, we are starting to find new approaches to educational leadership emerging, which although rooted in, and influenced by, traditional leadership theory, are yet different from it in that they do not focus on the characteristics or actions of leaders, but are more functionally oriented, in that they prescribe what in practice leaders should do. Chang (2012) identifies *technological leadership* as being such a type of functionally oriented leadership practice and explains that it “emphasizes that leaders should develop, guide, manage, and apply technology to different organizational operations so as to improve operational performance” and, thus, be effective in their role (Chang 2012, p. 328). To more easily understand what effectiveness in technology leadership precisely entails, however, it helps to first have a clear understanding of what educational leadership effectiveness, in general, is comprised of.

Competencies and Traits of Effective Educational Leaders

Bradley et al. (2017) explain, based on a number of research studies in the literature, that in a university setting, leadership roles require different types of knowledge and skills, such as: knowledge of academic policies and procedures, competency in managing finances and budget, interpersonal and communication skills, and emotional intelligence, and that these skill sets can either be developed through formal training or through experiential learning (e.g., learning on the job or from others) or through a combination of both. In a primary or intermediate or secondary school setting, the required skills and competencies of a leader are not that much different and, at all educational levels, the attributes of an effective educational leader happen to be more or less the same; they include: a solid understanding of the leadership context and its rules and regulations, efficiency in managing risks, provision of suitable and timely feedback, passion for education,

personal moral values, interest in and care for others, emotional intelligence, self-control, and resilience (Bradley et al. 2017). In a more structured sense, Murphy and Seashore (2018) identify nine principles of positive school/educational leadership, through which the characteristics of an effective leader emerge, summarized as follows:

- **Asset-Based:** Consistently concentrates on the assets brought to the institution by all stakeholders
- **Value-Centered:** Emphasizes and expresses in a clear and regular manner enduring values that form the basis of an institution dedicated to human development
- **Virtue-Based:** Consistently acts as an ethical and virtuous role model for others
- **Transcendent:** Sets and pursues a morally compelling vision that moves others to work for the common good
- **Relationally Grounded:** Focuses on developing positive relationships with all stakeholders
- **Means-Focused:** Understands the significant contribution of daily tasks of leadership to bringing about positive change
- **Growth-Based:** Encourages and supports personal and professional development of all school members
- **Authentic:** Demonstrates self-awareness and self-control, transparency, and individual consideration for others
- **Service-Grounded:** Displays a willingness to serve in order to nurture the humanity of all those impacted by the services of the organization

Technology Leadership in Education

Definition of Educational Technology Leadership

There are different definitions of technology leadership in education in the literature; nonetheless, they all share the emphasis stressed by Flanagan and Jacobsen (2003) that such leadership “is much more than resource acquisition and management”; for, it happens to have multiple dimensions, given the complex nature of educational institutions as learning organizations (pp. 124–125). An

example of a definition in the literature portrays technology leadership as representing all activities related to technology in an institution, including organizational decisions, policies, and procedures, as well as implementation (Anderson and Dexter 2005; Dexter 2011; Fletcher 2009 as cited in Sincar 2013, p. 1273). Another definition describes it as an integrated process involving the motivation of all school staff to learn, utilize, and integrate technology into the environments they are working in (Yorulmaz and Can 2016). While, in contrast, Chang (2012) defines it as an important turn away from exclusive school administration to a more current and multifaceted role of curricular and technological headship, which serves as an important strategy for improving academic quality and student outcomes. On the same lines, Abdul Razzak (2013) describes this approach to leadership as a leadership of the current digital milieu, which is capable of impacting all aspects of school capacity and of turning around schools into schools of the future, where preparation for the twenty-first century skills-like utilization of ICT in daily life and work – and beyond – takes place. Finally, Brown (2014) explains technology leadership by stating that, at its core, “it is about teachers, administrators, and technology leaders at all levels who embrace and realize the potential of educational technology to enhance student learning experiences, regardless of whether the learning occurs in a traditional or in a distance learning classroom” (p. 1).

Roles and Responsibilities of Technology Leaders in Education

Educational institutions as learning organizations are quite complex and their complexity amplified even more with the arrival of digital technologies, which placed additional demands on teachers and administrators alike. This is because the advancement of technology infused new energy into educational reforms in many countries around the world (Chang 2012), which became translated into official governmental mandates to organize schools and HEIs through ICT, and to integrate ICT in almost all their activities. Teachers and administrators, therefore, now find themselves

having to do more in order to cater to the needs of the new generation of learners, who are technology literate and digitally engaged and who, therefore, require different pedagogical conditions and approaches than the generations before them. This calls for the creation of a special type of culture within educational institutions that focuses on ICT integration and encourages exploration of new teaching, learning, and management techniques. Accordingly, leaders in such institutions are challenged to steer the ship toward the creation of such a culture, and a significant number of research findings point to the need for a technological leadership approach, which happens to have a multiplicity of dimensions. Before uncovering what these dimensions are, however, it helps to pave the way for them through reviewing some of what is found in the literature on the roles and responsibilities of technological leaders in education.

To begin with, Hall (2008) (as cited in Puckett 2014) explains that, “to be an effective leader in Educational Technology, one must identify what type of leader (s)he is. This type of identification requires sincere reflection” (p. 1). In addition, the technological leader should be decisive and directive since his/her main responsibility is to strike a balance between being a leader in the educational realm, on the one hand, and being able to motivate and appropriately manage a group of staff members in the technological realm, on the other (Puckett 2014). To be able to motivate others about technology and to succeed at guiding and managing their ICT-related attempts, leaders must be “actively supportive and learn the knowledge of ICT as well” (Betz 2000, as cited in Seyal 2015, p. 32), or else, they would not be able to provide their staff with adequate professional development opportunities needed for effective ICT integration in teaching and learning. They also would not be able to set and successfully implement educational technology plans (Seyal 2015), which, according to Picciano (2011), are required at all levels in an educational institution, in order to nurture the necessary ingredients for sustainable and effective ICT integration and development – ingredients like commitment, collaboration, and continuity. Such educational

technology plans usually focus among other things on: developing ICT-related policies and procedures; budgeting for ICT; securing a good technological infrastructure in the institution in terms of facilities, wired spaces, and connections; providing the needed resources for ICT integration (e.g., hardware, software, peripheral devices, multimedia, Wi-Fi, SMART boards, learning and information management systems, e-subscriptions, etc.); identifying potential ICT-related security issues and risks and setting strategies for managing them; recruiting sufficient and skilled technical support staff; providing professional development opportunities, which include both ICT literacy and ICT pedagogy, primarily for the teaching staff but also for the leaders in the institution (Abdul Razzak 2013). Last but not least, these plans are also needed for building a culture of acceptance of, if not enthusiasm toward, change and the adoption of new teaching and learning methods based on the utilization of ICT, where this culture is embedded in a positive environment that promotes, supports, and rewards creativity, inquiry, and innovation, especially when it is ICT-related (Flanagan and Jacobsen 2003; Chang 2012; Picciano 2011; Puckett 2014).

With respect to the teaching and learning methods that work best with ICT integration, research findings internationally have placed considerable emphasis on those associated with the constructivist model or approach, which represents the new educational paradigm of our time (Picciano 2011; Brown 2014; Flanagan and Jacobsen 2003). Brown (2014), for example, emphasizes that “for a leader to be successful in technology, he/she must be aligned with specific current best practices associated with desirable outcomes. Educational technology leaders can align themselves with Constructivist Methodology as part of best practices approach to improve teacher efficacy” (p. 1). By improving teachers’ efficacy in constructivist strategies, the expected result is that teachers will be more capable of continuously engaging students in authentic learning activities and opportunities, which are supported by the use of appropriate technology, and require and stimulate communication, inquiry, decision-making, and problem-solving

on the part of the learners (Flanagan and Jacobsen 2003). This, consequently, will result in enhanced student outcomes, since through it students “go beyond memorizing and reproducing theoretical models in the classroom” (Brown 2014, p. 2) to being engaged in posing their own questions, researching, and constructing their distinct knowledge and meanings of the world around them (Flanagan and Jacobsen 2003). Through such constructivist and ICT-enriched experiences and student engagement, learning can even extend “beyond the classroom walls through online collaboration, research and communication, sometimes with experts in the field” (Flanagan and Jacobsen 2003, p. 129). Since a key element of successful and effective ICT integration is student engagement, the technology leader’s responsibility therefore is to ensure a constructivist approach to teaching and learning within the educational institution, by which instructors’ roles change from being mainly the disseminators of knowledge to wise mentors and facilitators, who support students in their journey toward construction of meaning (Flanagan and Jacobsen 2003, p. 129).

In addition to playing a major role in setting the direction of teaching and learning within educational institutions, technology leaders must also be kept informed and remain up-to-date with the latest discoveries in both technology and learning theory, in order to thoroughly understand what skills students need for succeeding in the highly technical and competitive workforce they will be exposed to after graduation, and how to develop such skills (e.g., self-regulation, social competence, and adaptability) (Brown 2014). To be kept informed and remain up-to-date in such a manner, technology leaders themselves need to receive relevant training and professional development, whether in the form of internal workshops or mentoring sessions within their educational institutions, or external courses and certification within their communities or internationally, or even online courses, or better yet according to some researchers and practitioners, participation in professional learning networks (PLNs) or communities of practice. PLNs, in particular, are considered to be by some scholars crucial for technology leaders; as Brown (2014)

explains, technology leaders tend to usually feel “a sense of professional isolation” which, however, diminishes when one joins a PLN and which gets gradually replaced with “a real sense of being a part of, and being plugged into, a larger community of like-minded professionals” (p. 3). By the same token, Puckett (2014) sees PLNs and knowledge-sharing among best practices to be adopted by technology leaders and emphasizes that such leaders should not only join PLNs but, instead, should also promote such networks and other relatively new forms of professional development, such as collaborative action research, within their institutions, so as to create opportunities for staff to learn from one another and professionally grow. For, through such networks and collaborative research efforts, staff have the chance to discuss and reflect on what works and does not work in their classrooms and in those of others, and thus make use of these activities as platforms, not only for showcasing their success stories with ICT integration but also for inspiring others to continue with what they are doing and/or to incorporate new things into their classroom practices. Accordingly, ensuring the establishment and activation of PLNs and collaborative action research is an important responsibility among the myriad responsibilities of an effective leader in educational technology, which cannot and should not be neglected, especially when empirical research (e.g., Flanagan and Jacobsen 2003; Puckett 2014) has indicated that “educational leaders, who allow their staff to discuss and observe what works and does not work with technology implementation in other classrooms, will have better results with teachers’ attempts to integrate technology in the classroom” (Puckett 2014, p. 2). Positive results tend to also intensify in institutions where technology leaders themselves fulfill their responsibility of acting as inspiring role models of ICT integration and as providers of appropriate rewards and incentives for those “who become substantially involved with developing other staff and implementing technology in their school” (Picciano 2011, p. 222). For as Puckett (2014) maintains, “when staff members feel accomplished and appreciated, they are more inspired to continue with the work

they are doing and eventually incorporate new things into their regime” (p. 2).

In summary, therefore, educational leaders as leaders of technology have a multiplicity of responsibilities on their shoulders, with many hats to wear and many roles to undertake. From the review of the research literature provided above (and from other omitted studies), it is safe to conclude that the roles of the technology leader happen to be, as depicted by Yorulmaz and Can (2016), related to “technology-orientation, instructional program, infrastructure, facilitation, planning, communication, personal development, supervision, ethics, safety, technology budget, public relations, change and technology policy” (p. 48). The demands on the technology leader are, therefore, huge and call for appropriate and solid training, which can result in the acquisition of a crucial set of higher-order competencies and accompanying behaviors, in the development of some essential personal attitudes and mindsets. These competencies, behaviors, attitudes, and mindsets to be possessed by leaders of technology in education have been determined by several organizations within the context of educational technology standards and have been categorized in a number of dimensions. The section below provides an overview of a number of dimensions of technology leadership derived from a multiplicity of sources, mainly The International Society for Technology in Education (ISTE) standards of technology leadership, known as the *National Educational Technology Standards for Administrators* (NETS*A), and empirical literature on effective educational leaders in schools and HEIs in general, and on effective technology leaders specifically.

Dimensions of Educational Technology Leadership

Table 1 demonstrates, on the basis of NETS*A and the research findings of a number of studies in the empirical literature, the dimensions or areas in which technology leaders must be trained, in order to effectively fulfill their role in “supporting digital age learning, implementing technology, and transforming the educational landscape” (ISTE 2009 as cited in Sincar 2013, p. 1274).

Leadership on Information Technology in Education, Table 1 Dimensions of educational technology leadership or areas in which technology leaders must be trained

NETS*A standard theme	Standard description	Training needed <i>The technology leader must be trained to:</i>	Empirical research used
Visionary leadership	Educational directors inspire and lead people to develop and implement a shared vision to realize comprehensive technological integration across the organization and support perfectionism and transformation	Explore the direction and trends of technology development and the potential uses of technology in the classroom Develop a well-defined vision of how school improvement and effectiveness will be impacted by technology Communicate and share the vision with all stakeholders and continuously reinforce values related to the vision Strategically plan for technology integration and develop supporting policies and procedures for it	Yieng and Binti Daud (2017) Bennet (1996) Flanagan and Jacobsen (2003) Yorulmaz and Can (2016) Chang (2012)
Digital age learning culture	Educational directors create, support, and maintain a digital age learning culture offering suitable and attractive education for all students	Properly communicate and positively interact with others Provide support to encourage adoption of new teaching and learning strategies incorporating ICT Serve as a role model for promoting use of ICT in learning Meet the individual technological and pedagogical needs of all those involved in the learning process Participate in local, regional, and international learning networks and communities focused on innovation in ICT integration and encourage others to do the same	Yieng and Binti Daud (2017) Yorulmaz and Can (2016) Chang (2012)
Perfectionism in professional practice	Educational directors try to strengthen professional development and innovation activities to enhance student learning by means of the integration of contemporary technologies and digital resources	Plan and secure resources (e.g., finances, equipment, human resources, and time) for staff professional development Support staff in their individual professional development and growth plans Build opportunities for collaboration and knowledge sharing between and among colleagues	Yieng and Binti Daud (2017) Flanagan and Jacobsen (2003) Yorulmaz and Can (2016) Chang (2012)
Systematic development	Educational directors offer the leadership and management of digital age for the continuous development by making effective use of information and communications resources	Evaluate individual staff members' performance and growth in relation to set technological targets and utilize evaluation results to inform decision-making, planning, and improvement Research student achievement and grades and utilize the analyzed results for improving teacher performance and student learning Collect and analyze data on staff's ICT implementation, to identify technology savvy employees and develop plans on how to invest in them, retain them, and recruit others with similar profiles	Yieng and Binti Daud (2017) Yorulmaz and Can (2016) Chang (2012)

(continued)

Leadership on Information Technology in Education, Table 1 (continued)

NETS*A standard theme	Standard description	Training needed <i>The technology leader must be trained to:</i>	Empirical research used
Digital citizenship	Educational directors design a conception of related social, ethical, and legal responsibilities conducive to the development of digital culture	Promote, model, and develop policies and procedures for safe, ethical, and legal use of digital information technology Provide professional support to ensure equal access to technological resources and appropriate technology-use environments and spaces for the whole institution Establish institutional-wide understanding of an involvement in global issues through modern digital communication tools	Yieng and Binti Daud (2017) Flanagan and Jacobsen (2003) Yorulmaz and Can (2016)

Table 1 is divided into four columns, where the first column designates the theme of each standard of NETS*A, followed by the second column which includes a description of the standard, and then by the third column which indicates the training needs to be met. As for the fourth column, it lists the research studies highlighting the training needs derived from the NETS*A for technology leadership, which are standards that were originally intended to help educational leaders in the following tasks, as highlighted by Sincar (2013, p. 1274):

1. Understand their roles as technology leaders
2. Provide technological needs of all stakeholders
3. Fully accomplish technology integration in the educational process

Becoming a technology leader in an educational institution requires, therefore, a great deal of training in diverse areas. It also requires the fulfillment of many responsibilities. No matter how well-trained a technology leader is, however, and no matter how efficient they are in effectively fulfilling all that is expected of them, their position is not free of complications. On the contrary, the nature of ICT integration as a new movement in education, which demands transformation and change, brings along with it many challenges of diverse sorts. These challenges are usually referred to as “barriers” in the literature; they

carry the potential of hindering the success of ICT implementation in education and, consequently, impairing the effectiveness of the technology leader’s practices and attempts.

Barriers to Effective Educational Technology Leadership

Technology leaders experience diverse challenges in their educational practices, and Sincar (2013) groups these challenges under five major themes: *technology training, resistance, resources, equity, and bureaucracy*. A thorough search of the literature also conveys a general conformity in research findings on these themes.

In terms of *training*, the major challenge is the lack of it or the irrelevance or inappropriateness of what is provided. Even principals and senior administrators are in some cases not well-prepared for technology leadership responsibilities they are supposed to undertake and, as a result, find themselves lacking the necessary pedagogical competencies and experience needed to guide others in ICT integration. For this reason, we find in many schools the phenomenon of what Flanagan and Jacobsen (2003) call “informal technology leaders,” who emerge “from classrooms, libraries, and computer labs to take up the difficult task of planning for technology integration, and supporting distributed and often uncoordinated efforts by enthusiastic teachers” (p. 128). In many cases also, we find ICT technicians playing the leadership role in the place of the



untrained principal or senior administrator, especially when the latter lacks sufficient knowledge of how hardware and software selections/choices impact student learning and outcomes (Flanagan and Jacobsen 2003, p. 128). For this reason, training resulting in ICT literacy and ICT pedagogy is emphasized by many scholars as a key factor in the context of technology leadership (Abdul Razzak 2013; Chang 2012; Flanagan and Jacobsen 2003). One problem reported by educational leaders, however, is that their job is highly demanding and that they spend most of their time on solving problems in their schools and, as a result, do not find time for working on their own professional development (Sincar 2013). Nevertheless, finding ways and time for ICT-related professional development is a must for any educational leader who aims at making technological innovation a reality in their institution, no matter how overwhelmed they may be. For, without such professional development of leaders, it would not be possible for them to support the development of teachers and others involved in the core functions of education within their institution, whom themselves are in need of “responsive and flexible professional development opportunities that focus on technology integration and design, rather than computer applications alone” (Flanagan and Jacobsen 2003, p. 127). Such professional development in ICT integration and pedagogical design is something that teachers are in dire need of, since considerable research findings indicate that many teachers lack the basic competencies and knowledge for designing technology-based lessons and, many times, they try to integrate technology without fully understanding it as a concept or comprehending the context in which it should be utilized (Abdul Razzak 2013; Jenkinson 2009 as cited in Puckett 2014, p. 4). Instructors involved in online teaching or e-learning, in particular, are in need of training which focuses on appropriate design of online activities and lessons and on relevant modes of interaction in an online environment; for, as Abdul Razzak (2016) has found, too often and in very few institutions “are web-based course management software or as they are called, learning management systems

(LMS), like BlackBoard and MOODLE being activated by some faculty for more than posting course announcements, course documents, supporting reading materials, assignments, and grades” (p. 885). There is no substantial evidence, therefore, of online teaching methods being utilized to capitalize on students’ higher-order cognitive skills, such as critical thinking and creativity. Besides, many instructors “are still uncomfortable with designing basic online activities to begin with” and, accordingly, need training in this area first before they receive training on how to design online activities that both engage students actively and enhance their higher-order thinking skills and deep learning (Abdul Razzak 2016, p. 885).

With respect to *resistance*, it usually comes from the side of the teachers; “while educational technology may be exciting to some, to many educators it is highly stressful, as it is uncharted territory” (Puckett 2014, p. 4). Thus, it is natural that teachers do not find it easy to have to make changes to the teaching practices that they have been accustomed to using for years. Teachers who are close to retirement, in particular, are usually the most resistant to using technology in education and they sometimes, unfortunately, adversely influence younger teachers’ motivation and behaviors related to ICT implementation (Sincar 2013). This constitutes a challenge for technology leaders since without strong teachers’ buy-in and commitment to ICT integration, the leaders’ role of creating, supporting, and maintaining a culture of digital age learning gets impeded.

In addition, several issues with *resources* comprise a barrier to effective technology leadership. What is meant by resources here is both material and human resources. With respect to the material resources, the lack of availability of sufficient and adequate technology spaces and physical facilities, as well as the lack of availability of up-to-date technology, pose a challenge to technology leadership in many institutions, especially in communities with low income (Thomas and Kzenek 1991; Richardson and McLeod 2011 as cited in Sincar 2013, p. 1275). Lack of availability and insufficiency of physical resources is not the only

barrier, however. In some cases, the challenge for technology leaders has to do more with planning for resources than their availability, and this is why it is not uncommon to find many schools that actually have the latest technologies and very expensive computer laboratories, but which nevertheless are not making use of them for meaningful and constructive technology-enhanced lessons. The problem here is with resources' planning that happens to focus mainly on the acquisition of hardware and software and on the wiring of facilities without much regard for "substantial organizational and cultural changes that are necessary to support appropriate use of technology to enhance student learning" (Flanagan and Jacobsen 2003, p. 128). Other challenges related to human resources in particular that technology leaders face have to do with the inability to find skilled technology coordinators and the insufficiency of technical personnel to support educational institutions with their troubleshooting issues (Sincar 2013).

Among the barriers to technology leadership also are some *equity issues*. These issues are represented through an unequal distribution of educational-based technologies among schools and HEIs in most countries. This happens because some educational institutions have or receive more funding and resources than others and, many times, the disadvantaged ones are located in low-income communities or areas (Flanagan and Jacobsen 2003; Richardson and Mcleod 2011 as cited in Sincar 2013, p. 1275). These equity issues have the potential to impact the core functions of teaching and learning; when students do not have sufficient and well-prepared and adequate facilities, they tend to fall behind in the use of education-based technologies (Sincar 2013, p. 1282), which can have an adverse impact on their achievement of expected learning outcomes, especially in comparison to other students who study in advantaged institutions. Accordingly, a major challenge for technology leaders is to ensure their educational institutions "are places where inequities are eradicated rather than exacerbated by the integration of technology" (Flanagan and Jacobsen 2003, p. 127). On the

same lines, technology leaders need to ensure that there is something for everyone in terms of educational-based technologies, meaning they need to be sensitive to diversity in terms of gender, economic background, ethnicity, and language, as well as to other systemic barriers that impact students' use of technology (Flanagan and Jacobsen 2003). Teachers' and students' different learning approaches, in particular, need to be taken into consideration and catered to. This is in addition to a student's achievement levels, where in many cases a need may present itself to have to provide special computer-assisted instruction (CAI) for lower-achieving students and students with identified disabilities. Several research studies have indicated that such groups of students tend to make significant gains with the application of CAI as a supplemental activity to teacher-directed instruction and tend to benefit more from it than from other interventions such as additional traditional teaching and/or drill exercises (Hall et al. 2000; Jeffs et al. 2006).

Finally, *bureaucracy* is reported in many research findings as being one main challenge that slows down the practices of technology leaders in education (Nance 2003 as cited in Sincar 2013, p. 1275). Bureaucratic obstacles are also considered as the most difficult to overcome. Usually these types of obstacles lead to delays in, if not total prevention of, the introduction of new technologies into educational institutions; they also raise difficulties in the fulfillment of some educational demands (e.g., training, coaching, mentoring, or curriculum coordination) related to technology. As a result, this can have negative effects on the quality of education, because of missed opportunities that pass by untapped, due to delays or other forms of obstacles resulting from bureaucratic processes. The technology leader's effectiveness, consequently, gets destabilized in the course of events.

Despite the diverse barriers to technology leadership, many of them are surmountable, especially with a proactive approach, and with appropriate training, passion for education, and enthusiasm for innovation. Successfully embodying many leadership roles at the same time is also important.

In particular, as Flanagan and Jacobsen (2003) conclude, the technology leader should be effective simultaneously as a leader: (1) of learning, (2) of student entitlement, (3) of capacity building, (4) of community, and (5) of resource management.

Conclusion

To sum up, educational leaders are key factors in ICT integration in schools and HEIs. As technology leaders, their role is central yet not easy; their effectiveness in this role impacts a multiplicity of core practices in education, primarily: instructors' and students' learning of technologies; instructors' use of technologies in designing and teaching lessons; and students' learning with and through technology. The more successful such leaders are, the greater the positive influence they have on teachers' professional development and actual implementation of technology-infused teaching, which in turn results in improved student achievement and learning outcomes. To have powerful influence of this kind and to be able to sustain it, it is mandatory for technology leaders to demonstrate the following attributes and behaviors:

- Be vision-oriented with respect to the direction of educational technology
- Engage in effective strategic planning (i.e., setting goals) that is based on an assessment of their educational institution's needs in relation to all educational technology requirements (equipment, hardware, software, human resources, infrastructure, etc.)
- Possess the capacity to motivate their staff to become engaged in ICT-related activities
- Develop strong personal buy-in and commitment to educational technology
- Go above and beyond securing access and sustaining effective implementation of educational technology, i.e., they need to be excited and passionate about ICT in education
- Be knowledgeable and stay up-to-date about the latest technologies and educational technology practices
- Be role models of successful ICT integration within their institutions
- Promote an inviting school culture toward innovative educational technology implementations and practices
- Ensure the recruitment of committed educators in terms of their attitude/practice toward educational technology and ensure for them the provision of sufficient and adequate professional development training opportunities related to educational technology implementation
- Encourage collaboration among teachers so that they work together on educational technology projects and share experiences and practices and learn from one another
- Establish partnerships with community members (parents, businesses, software developers, other schools and HEIs, etc.) that could benefit the educational technology initiatives in their institutions
- Value any educational technology initiative/attempt and celebrate educational technology success stories within the school
- Provide appropriate incentives for technology savvy staff implementing educational technology
- Support and encourage the utilization of educational technology as a vehicle for inclusion (i.e., including also students with disabilities)
- Promote the implementation of action research in relation to educational technology implementation, so that teachers and other staff can learn from their own mistakes and experiences and can develop themselves on the job or in the field

Only by demonstrating such attributes and behaviors can technology leaders have a better chance at effectively leading and preparing their institutions not only for this decade but also for decades to come. Only then, also, can they expect to witness good, if not excellent, success stories of ICT integration within the educational communities they lead; as Puckett (2014) puts it, although "a leader must expect excellence; (s)he must also display excellence" (p. 1).

Cross-References

- [Implementation of ICT in Secondary Schools](#)
- [IT in Educational Institutions, Planning and Development of](#)
- [Teacher Education and Professional Development for Technology Integrated Teaching](#)
- [Technology Enhanced Learning](#)

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Learning

- [Distance Learning](#)
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Learning Analytics

- [Educational Assessment, Educational Data Mining, and Learning Analytics](#)
- [Multimodal Learning Analytics](#)

Learning and Training with Digital Technologies

- [Sustaining Digital Technology Use in Professional Communities](#)

Learning Behaviors in Programming

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How students go about their learning has been widely researched from various perspectives. Deep and surface learning is a key perspective

taken by many researchers. Another view has been to look at good and poor learning tendencies. Several models of how students experience the learning of IT and programming have also been developed. Yet another perspective is that of student engagement: behavioral, emotional, and cognitive. This entry presents these various perspectives of learning behaviors.

Deep and Surface Learning

Various authors have sought to explore how students learn from the perspective of surface learning and deep learning. While the majority of these studies (and models developed) are from a general education perspective, a few studies have focused specifically on the information systems, computer science, and accounting contexts.

Biggs contends that the approaches to learning are formed by motives (intention) and strategies (actions). It is the learning approach the student chooses (surface, deep, or achieving) that affects the quality of the learning outcome (Biggs 1989; Biggs and Tang 2007, 2011; Carbone 2007):

- *Surface Approach*

The surface approach is based on an extrinsic motivation such as choosing to do a degree at university as a means to some other end such as obtaining a better job or to achieve a pass as a result of having to take a subject that is irrelevant to the student's program. This approach arises from the intention to get the task out of the way with minimum effort while appearing to meet the task requirements. It involves "cutting corners" to give the impression that the task was properly done; this is to avoid failure. Students focus on the isolated items and treat these independently of each other or to other tasks. They focus on the literal facts missing their meaning (rote learning). There is also a presence of negative feelings such as anxiety, cynicism, and boredom. There may be other factors that encourage a surface approach such as insufficient time, misunderstanding requirements, high anxiety, or a cynical view of the subject or of the teaching context itself.

- *Achievement/Strategic Approach*

The achieving approach is based on a particular type of extrinsic motivation: the need to achieve through high grades using a surface approach. The strategies used consist of organizing time, working space, and syllabus coverage in the most cost-effective way. Their approach is systematic, planning ahead and allocating time to tasks in proportion to their earning potential.

- *Deep Approach*

The deep approach is based on an intrinsic interest in the subject matter that is being learnt. The strategy used aims to maximize understanding so that curiosity is satisfied. Students feel the need to engage in the task appropriately and meaningfully. They feel a need-to-know so they focus on understanding the underlying meanings rather than the literal aspects. They seek to integrate the parts with other tasks and also with the big ideas in the domain.

The student reads widely, discusses with others, and may play with the task in order to hypothesize how it relates to other known or interesting items. Students generally have positive feelings when using a deep approach such as feelings of interest, challenge, and exhilaration. Factors that promote a deep approach include an intrinsic curiosity or determination to do well, an appropriate background knowledge, and a well-structured knowledge base.

A model more specific to information systems was developed by Cope (2000), who sought to investigate the relationship between approaches to learning and levels of understanding of the concept of an Information System (IS) in undergraduate students (Cope 2000, 2002, 2003).

- *Surface Approach*

A surface approach to learning about IS involved a series of isolated and generally unrelated learning and assessment tasks that had to be completed to pass the course. Knowledge was experienced as facts contained in lecture notes and summaries, formulae, and skills on how to use software. The intentions

of acquiring the knowledge were to be able to recall the knowledge or to apply the memorized procedures in assessment situations.

- *Deep Approach*

A deep approach to learning about IS involved seeking meaning of the content from the learning tasks and assignments with the intent of developing a deep personal understanding that went beyond the immediate task. Meaning was sought through relating the content in the learning tasks to other content from the same course or a different course. Understanding was experienced as having an internalized picture of the content that could be used to link with new material or explain to others.

Cope (2003) described that the educationally critical characteristics that lead to the development of a deep understanding are:

- An intention to seek a deep understanding of the concept of an IS
- The process of seeking and relating the meanings associated with a broad range of different perspectives on the concept of an IS, including perspectives in personal experiences beyond the academic setting and in studies outside IS and computing courses
- An awareness of one's own understanding of the concept of an IS and the approaches being used to learn about IS

Learning activities should center on students being aware of and taking charge of their own approaches to developing a deep understanding of the concept of an IS (Cope and Prosser 2005).

While the Biggs model has been widely cited in computing education literature, few studies were found that specifically investigated deep and surface learning approaches in the programming context. One major study conducted over multiple universities, in multiple countries, of introductory programming students, found that a deep approach to learning was positively correlated with marks in programming, while a surface approach had a negative correlation to marks (de Raadt et al. 2005; Simon et al. 2006).

Learning Behaviors in Programming, Table 1 Poor learning tendencies (Baird and Mitchell 1991; Carbone 2007)

Learning tendencies	Characteristics
Superficial attention	This involves skimming over a communication, with no attempt to actively process the information in order to generate personal meaning
Impulsive attention	Some parts of a communication that appear interesting are attended to, but others that may be major points are overlooked
Staying stuck	Lack of any strategy to cope with getting stuck except to call for help. No attempt to return to the instructions, reflect on the strategy selected, analyze what has been done so far, or consider alternative approaches
Premature closure	Ceasing work on a task in the genuine belief that it is finished when in fact some things may not have been done
Inappropriate application	Blind application of a memorized procedure in a situation where it is not applicable
Non-retrieval	This occurs when no attempt is made to retrieve one's own existing views and understandings which are relevant to the knowledge being presented. The learner is unsure of conflicts between the school knowledge and their personal views
Lack of internal reflective thinking	The learner is not thinking reflectively about the content as presented "internally" (i.e., within the boundaries of the subject). Each lesson, activity, or even instruction is seen as isolated from the others
Lack of external reflective thinking	The learner makes no attempt to link the content of one subject with the content outside the boundaries of the subject (i.e., world or other subjects)
Ineffective eradication	Persistent reappearance of apparently changed misconceptions or alternative explanations

Another study investigated deep, surface, and strategic learning approaches in programming students. They found that a strategic approach had a strong positive relationship with performance, a surface approach had a strong negative relationship, but a deep approach only had a weak positive influence. They conclude that the students who take a strategic approach are most likely to be successful (Hughes and Peiris 2006).

Learning Tendencies

An alternative view to learning approaches is the concept of learning tendencies (Baird and Mitchell 1991; Baird and White 1982). Baird and Mitchell (1991) describe poor learning tendencies as "descriptions of poor thinking habits – of deficiencies in the way learners tackle tasks or process information." Baird and Mitchell found that poor learning tendencies were frequently responsible for poor learning performance, but often unintended, and that students were unaware of them, even by those with a good level of commitment.

Carbone (2007) used these poor learning tendencies as a "base for determining the type of

thinking undergraduate IT students did not do as they engaged in their programming tasks." A summary of these poor and good learning tendencies is shown in Tables 1 and 2.

Carbone (2007) also found that programming students can suffer from poor time management. Failed attempts to complete a working system within the timeframe allowed led students to prioritize the activities to complete and choose those that would achieve the best grades possible. They also abandoned their attempts to understand the problem and opted to copy slabs of code from the textbook without fully understanding it (Carbone 2007; Carbone et al. 2009).

Ways Students Experience Learning IT and Programming

Other studies in the way students approach their learning in the fields of computer science (CS) and IT have demonstrated that students experience their learning in different ways.

Berglund et al.'s study presents seven categories which describe the way students act to learn computer science, where the more advanced categories with a higher number describe a more

Learning Behaviors in Programming, Table 2 Good learning tendencies (Baird and Mitchell 1991; Carbone 2007)

Summary	Possible actions
Seeks assistance	Informs teacher when they don't understand
	Asks teacher why they went wrong
	Informs teacher what they don't understand
Checks personal progress	Checks work against instructions, correcting errors, and omissions
	Refers to earlier work when stuck before asking the teacher
	Checks personal comprehension of instruction and material
Plans and anticipates	Anticipates and predicts possible outcomes
	Plans a strategy before starting
	Explains purpose and results
Reflects on work	Checks teacher's work for errors and offers corrections
	Seeks links between adjacent activities and ideas
	Seeks links between different topics
	Independently seeks further information
Links to beliefs and experiences	Seeks links between different subjects
	Asks inquisitive but general questions
	Offers personal examples which are generally relevant
	Seeks specific links between school work and personal life
	Searches for weakness in their own understandings
Assumes a position	Checks the consistency of their explanations across different situations
	Suggests new activities and alternative procedures
	Expresses disagreement
	Offers ideas, new insights, and alternative explanations
	Justifies opinion
	Reacts and refers to comments by other students
	Challenges the text or an answer the teacher sanctions as correct

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sophisticated way of acting to learn. Categories 1–6 describe learning CS through (Berglund and Wiggberg 2008):

1. *Learning to use application programs*, focusing on learning the tools that are used and neglecting the other aspects in the field taught by the computer science community
2. *Learning CS through learning about isolated concepts*, focusing on learning concepts/topics of CS rather than what can be done with what is learnt
3. *Learning CS through consolidating what is already known*, where deeper insights about CS concepts are sought but concepts are still seen in isolation
4. *Learning CS through analyzing systems*, focusing on learning the whole in order to explore the different concepts which make up the parts
5. *Learning CS through integrating systems*, focusing on learning by splitting the units in the software system into pieces and analyzing the parts and then putting the components together, as a way to learn about and to create a system
6. *Learning CS through giving meaning to concepts*, focusing on seeking personal insights and personal meanings to the CS concepts
7. *Learning CS through developing as a professional*

Peters et al. (2014) phenomenographic study focused on understanding the distinct ways students participate in CS and IT using the idea of participation from Wenger's social theory of learning. Participation in CS/IT was experienced as:

- *Using*: to make use of what exists for various purposes.

- *Inquiry*: activities that aim at understanding, learning, and informing.
- *Creating things*: to produce things that were not there before. The aspects that are related with this category are the outcome and the process of doing and doing with others.
- *Systematic problem-solving*: this includes using methods, ways of thinking, and systematically working with others to create things.
- *Creating for others*: this includes taking into account the user's perspective in the process of creating and problem-solving.
- *Continuous development*: as a continuous process of improvement.
- *Creating knowledge*: to develop new solutions, (to do research).

Introductory programming courses often have highly bimodal grades – many students failing or obtaining high grades. Robins (2010) proposes this may be due to what he calls “learning edge momentum” (LEM). Concepts in the programming domain are tightly integrated, where almost every concept depends on many others. Successful learning of a concept makes it easier to learn further related concepts. In contrast, unsuccessful learning of a concept makes it harder to learn other closely linked concepts. This then creates a momentum towards a successful or unsuccessful outcome (Robins 2010).

Another factor that explains the LEM effect is that “we learn at the edges of what we already know.” “Understanding (on a short time scale) and learning (over a longer period) depends on fitting new material into the context of existing knowledge” (Robins 2010).

Bruce et al. (2004) investigated how first-year university students experience the act of learning programming. The experiences are described as five different categories that describe how learning to program is experienced:

- *Following*: describes the experience as following the structure of the unit to get through it (struggling to keep up and focusing on the tasks that gain marks).
- *Coding*: describes the experience as learning to code (focusing on learning the syntax of the

programming language expecting intensive direction from experts and teachers).

- *Understanding and integrating*: describes the experience as seeking understanding of the big picture, experimenting with code, and becoming more proficient with coding in order to understand the concepts and apply them in different ways.
- *Problem-solving*: describes the experience as learning to do what it takes to solve problems. The primary focus is solving the problem, and coding is seen as part of the learning process.
- *Participating or enculturation*: describes the experience as learning what it takes to be part of the programming community and culture. This involves understanding what the programmer thinks and does in order to communicate with other programmers in that community.

Engagement

Engagement has been described as a multi-dimensional construct that integrates and blends the concepts of behavior, emotion, and cognition (Fredricks et al. 2004). Engagement has been associated with positive academic outcomes, such as achievement and persistence in school. It has also been found to be higher in classrooms with “supportive teachers and peers, challenging and authentic tasks, opportunities for choice, and sufficient structure” (Boekaerts 2016; Fredricks et al. 2004).

Three different types of student engagement have been described (Carbone 2007; Fredricks et al. 2004):

- *Behavioral Engagement*
 - Positive conduct, such as following rules and adhering to classroom norms, as well as absence of disruptive behaviors such as skipping school and getting into trouble
 - Involvement in academic tasks which includes behavior such as effort, persistence, concentration, attention, asking questions, and contributing to class discussion
 - Participation in school-related activities such as athletics or school governance

Behavioral engagement contributes towards positive academic outcomes.

- *Emotional Engagement*

Students' affective reactions in the classroom towards teachers, classmates, and school – both positive and negative. These include interest, boredom, happiness, sadness, and anxiety and are considered to influence the willingness to do work. These emotions overlap with many of those reported in the motivational literature.

- *Cognitive Engagement*

“Effort directed towards learning, understanding, mastering the knowledge, skills or crafts that the academic work is intended to promote” (Fredricks et al. 2004). Cognitively engaged students show flexibility in problem-solving and the ability to cope with failures. They use deep-level strategies, exerting greater efforts to achieve a more thorough understanding. They want to go beyond the requirements and prefer a challenge.

The concept of engagement has been widely studied in recent years (Boekaerts 2016; Eccles 2016). Azevedo (2015) found more than 32,000 articles in PsycINFO about engagement published in the last 14 years. Researchers have broadened the original three-dimensional framework of engagement to include agentic, self-regulatory, and social-behavioral components (Boekaerts 2016). Influences on engagement have also been explored, such as teaching staff, peers, structure, and task characteristics (Fredricks 2011).

In a recent study of engagement in first year ICT students, Sheard et al. (2010) used the three types of engagement as a framework to analyze the data. Low behavioral engagement was identified as poor class attendance and lack of weekly study time, with students spending half of the recommended time. They also displayed a lack of organizational ability where they put low effort at the start, which must be increased when assignments are due. Irregular study patterns may be also influenced by outside work commitments (Sheard et al. 2010).

Low cognitive engagement manifested itself as a low involvement and investment in study time.

While teachers expected students to work more independently and to read the lecture notes prior the lecture, few did. Students, on the other hand, expected more guidance, concrete examples to learn from, and specific topics to learn for the exam (Sheard et al. 2010).

Affective engagement was related to the level of interest students had in the course content. Students were keen to learn the applications but not that interested in fundamental concepts. Differing levels of ability were found to influence engagement. Highly engaged students have an interest in the area and have already learnt some ICT on their own or from high school. In contrast, lower engaged students failed to attend classes and avoided consulting teaching staff (Sheard et al. 2010).

Learning Outside the Classroom

With the wide adoption of learning management systems and course materials being accessible online, students now have much greater flexibility in choosing the mode, place, and time of their learning (Sheard et al. 2013). Relatively few studies, however, have investigated programming student study habits outside the classroom.

In a survey of programming student study habits, Chinn et al. (2010) found that “students engaged in a wide range of study behaviours in terms of time spent and use of resources.” Students spent as much time accessing the Internet as reading the textbook. While the majority of their students said they preferred to study alone, they also reported that 95% of students spent at least some time each week talking to friends and classmates about the unit. Their female students tended to work more with others than the male students, and they reported this as being a negative factor on their results (Chinn et al. 2010; Sheard et al. 2013).

A follow-up study by Sheard et al. (2013) sought a more holistic understanding of the study habits of programming students. Students reported studying in various locations, such as at home, on campus, or on the train. Many students reported spending minimal study time after

tutorials and then spending intense periods of study time during assignment/exam time.

Students reported using various study techniques outside the classroom. Most reported reading lecture notes, summary notes, and the textbook (as a reference source or for code examples). Many also heavily relied on online materials. Most students also reported attempting lab and tutorial exercises outside of class time, but only some tried running code examples. Students found that working with others was helpful; however, most preferred to work on their own (Sheard et al. 2013). In a recent study of programming study habits, Willman et al. (2015) found that “students who receive the highest grade start and finish their work early, do not work on weekends, and do not work at night.”

Summary

This entry presented various perspectives of student learning behaviors: deep and surface learning, good and poor learning tendencies, how students experience the learning of IT and programming, and student engagement. Much of this research, however, has been focused on how students learn inside the classroom. More understanding is needed on how students are learning programming outside of the classroom.

Cross-References

- [Learning Programming, Student Motivation](#)
- [Learning Programming, Success Factors](#)

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Learning Management Systems, An Overview

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Synonyms

[Course management systems](#); [E-learning](#); [Learning content management systems](#); [Online learning](#)

Introduction

There can be no doubt that technology has transformed the way education is delivered to people across the globe. We now live in an interconnected world where the traditional concept of formal learning, taking place in a single physical location, is becoming increasingly less relevant. Modern learners are becoming dissatisfied with the stand-and-deliver approach to education that dictates attendance times, learning venues, and modes of participation. The emergence of sophisticated communication technologies and mobile devices has enabled a

new generation of information consumers to satisfy their demands for knowledge without the need to meet in a physical location. Software vendors, open-source developers, and educational institutions, cognizant of this development, have embraced systems that can facilitate the management of courses and engagement with students remotely. The technologies that facilitate the provision of courses over long distances are broadly termed “learning management systems” or “LMSs.” Learning management systems can be defined as web-based software platforms that provide an interactive online learning environment and automate the administration, organization, delivery, and reporting of educational content and learner outcomes.

Acronym Confusion in the Online Learning Space

There are many terms associated with online learning and the technologies that have evolved to support it. One persistent area of confusion is in the definition of the acronyms: *CMS* and *LMS*. The term *CMS* is often associated with two distinctly different software applications: “content management systems” and “course management systems.” Content management systems are essentially software applications designed for the creation and management of digital content in a collaborative environment. Course management systems on the other hand, according to Watson and Watson (2007, 29), are:

used primarily for online or blended learning, supporting the placement of course materials online, associating students with courses, tracking student performance, storing student submissions and mediating communication between the students as well as their instructor.

To further complicate matters, some vendors and academics prefer to use the acronym *LCMS* which stands for “learning content management system” when referring to content management systems. The difference between a *LCMS* and a *LMS* is that the latter is broader in scope and includes the ability to track learner progress through an online course. It is a gray area where

CMSs end and LMSs begin and many vendors, users, and institutions regard the terms CMS and LMS as synonyms. In this entry, the term LMS will be the only acronym used to refer to online learning platforms.

The Inclusion of LMSs in Distance Education

The history of educational technology is a reminder that it's not the machine that matters — it's finding the tool that best serves your educational objective.
Thornburg (2014, 27)

The history of learning management systems has its roots in distance education. Countries such as Australia, with a geographically dispersed population, adopted measures early in their history to enable access to education for students who could not attend formal places of learning. One of the most prominent manifestations of distance education in Australia was the School of the Air (a correspondence school) which opened to the airwaves in 1951 and is still in operation today in some remote communities. The vocational education and training (VET) and university sectors in Australia also have a rich history of distance education where, prior to the advent of the Internet, communication and the dissemination of learning materials was largely conducted via regular mail services. The availability of dial-up Internet services to most Australians by mid-1995 meant that distance education needed a radical overhaul and *snail mail* was no longer a viable option to sustain distance education services.

Perhaps it was Sidney Pressey's creation in the early 1920s of a "learning machine," a device that could administer questions through a window prompting the user to select a response out of four choices, that spurred the development of the first online LMSs. Or maybe it was the work of a Canadian company, SoftArc in 1990 who built the first stand-alone learning system deployed on Macintosh personal computers, that encouraged software developers to dream of an online learning space. Whatever the inspiration, the arrival of the Internet was set to revolutionize the way

people communicated and engaged with each other and education providers realized that they would have to adapt to this brave new online world. The earliest manifestations of electronic LMSs were little more than a platform for the dissemination of learning materials online. These systems could broadly be categorized as belonging to one of two camps: proprietary and open source. One of the earliest proprietary systems was WebCT, developed at the University of British Columbia in 1995. The creation of WebCT as an online learning platform was inspired by research suggesting that academic performance could be enhanced by the provision of web-based resources. At the height of its use, WebCT was the most widely used LMS globally with over 10 million users in 80 countries. WebCT was later acquired by Blackboard Corporation who phased out the WebCT name in favor of the Blackboard brand.

Open-source systems by contrast, were developed collaboratively by software specialists with a view to making the source code readily available to organizations and individuals free of charge. They were initially popular with universities and colleges who could readily download the source code, adapt it to their own circumstances, and build their own tailored LMS solutions. A prominent example of an open-source system in operation globally today is Moodle. Moodle was developed by Martin Dougiamas with the first version released in August 2002. The acronym Moodle stands for "Modular Object Oriented Dynamic Learning Environment." The system was developed based on a constructivist philosophy emphasizing the role of learners as creators of content and not merely spectators. Moodle is arguably the most popular open-source LMS in use today with almost 100,000 registered sites in 229 countries.

What Are the Features of LMSs That Make Them Great?

A robust, high-quality LMS is a vital tool to the success of any online course and can



Learning Management Systems, An Overview, Fig. 1 LMS feature categories

make or break an institution's reputation in the highly competitive education market. LMSs not only need to provide content to learners, but they must also facilitate timely and accurate communication between learners, course facilitators, and other institutional stakeholders. Yildirim et al. (2004, 125) emphasize that in addition:

an LMS should be dynamic; that is, it should be active, flexible, customizable and adaptable.

Whether a LMS is proprietary or open source, it will need to be capable of executing a variety of functions that work together to provide a seamless experience for the user. These functions include the capability to disseminate knowledge, assessment of learner competency, the recording

of learner attainment, support for online social communities, communication tools, and system security. Figure 1 illustrates the categories of features that are expected to be present in most high-quality LMSs.

Course Management

Course management features encompass a LMS's capacity to deliver timely relevant course material to enrolled learners. It would include such features as content management and control, class scheduling, and content-audit capabilities. The capacity for users to contribute to content creation in their own personal space could also come under this domain.

Assessment

Assessment is a critical function of LMSs. A LMS must be able to support the collection and storage of assessable tasks, along with the assignment of grades and feedback for each learner. Assessable tasks can include assignments, tests, projects, and portfolio evidence provided by the learner. For institutions in the VET space, the capability to automatically generate compliance reports is particularly valuable as it facilitates compliance with quality standards. LMSs should also be capable for providing learners with real-time information on their progress in a course along with relevant feedback generated by the instructor.

Tracking Progress

Attrition of learners is an issue that concerns many institutions. In an online environment, the experience has been that learners are at a greater risk of withdrawing from programs because of the lack of face-to-face contact. The ability to track user engagement in a course is therefore considered an important feature. User tracking analytics can include log-on frequency, time spent in different sections of a course, communication interactions, and the number of resources downloaded. With appropriate reporting functions, course facilitators are able to detect possible student performance deficits and intervene before course withdrawal or termination becomes likely.

Gradebook

Gradebook functions include all LMS capabilities that facilitate the dissemination of assessment information to learners. Such functions include individual scores of assessments, instructor feedback, and student attendance. The ability to generate aggregate reporting information such as class grades, item score analysis, and at-risk student information is included in this category.

Communication Tools

Communication tools within LMSs can be broadly classified as synchronous or asynchronous. Asynchronous tools support one-way communications such as e-mail, discussion boards, or Wikis. They are often preferred by course facilitators because they can be initiated in an ad hoc manner. Synchronous tools, on the other hand, are two-way communication tools supporting real-time information interchange. Examples include instructor-led videoconferences and interactive message boards. This latter class of communication tools is often seen as important to replicating traditional classroom-based communications, thereby fostering a sense of community among online learners.

Social Connectivity

One of the great criticisms of LMSs is the lack of inherent community in online learning. Features that try to replicate a social environment online include discussion forums, live chats, and videoconference tools as discussed in the previous section. Some LMSs even have features that monitor learner interactions with communication tools and are considered invaluable for courses that mandate class participation as an assessable component of a course.

Security and Privacy

Security and privacy are of paramount importance to the success of an online course. Important security features in LMSs include user authentication, access verification, password integrity controls, and intruder detection. Privacy controls are also important to ensure that sensitive information is made available to the intended recipient only.

Ubiquitous Access

People are increasingly dependent on their mobile phones to connect to the Internet. It therefore stands to reason that online course participants need to interact with LMS course environments using their mobile devices. Most LMS providers design course content as responsive HTML pages and are therefore accessible by most smartphones and other mobile computing devices, thus providing ubiquity.

Proprietary or Open-Source Systems: Which Way to Go?

One of the major considerations that an organization has in choosing a LMS is whether to opt for a proprietary or an open-source system. There are pluses and minuses to both approaches, and the choice will largely depend on the resources and expertise the organization maintains in-house and the degree of control they wish to exercise over the administration and future development of the system. Proprietary systems come with the advantage of being developed by a company that specializes in the design and deployment of online learning solutions. The acquisition of a proprietary system usually includes installation and end-user training and does not require any configuration on the part of the client. However, the client institution has limited control over the features provided in the proprietary system and certainly would be unlikely to have access to system source code.

The alternative approach is for an organization to develop its own LMS based on readily available *open-source* code. Moodle, for example, has a popular following and maintains a system of version control and technical specifications for each version.

Krouska et al. (2017, 2) described Moodle as follows:

Moodle is a LMS designed to provide educators, administrators and learners with a single, robust, secure and integrated system to create personalized learning environments. It has a wide range of

standard and innovative features for supporting teaching and learning process. Moreover, it allows for extending system functionality using community sourced plugins.

The source code for Moodle is freely downloadable, and each specific iteration has its own set of installation instructions. Once the source code for a LMS has been downloaded, organizations are free to adapt the code to suit their particular circumstances. Universities and colleges are among the most prolific users of open-source LMSs. This can be attributed to the availability of in-house IT expertise in most universities and colleges and the professional curiosity among IT system decision-makers to develop an understanding of LMS technology through its implementation.

In-House Housing of Data or Cloud Based

Cloud-based LMS solutions are rapidly developing as a viable alternative to on-site installation for client organizations. The choice of adopting a cloud-based LMS largely depends on the degree of confidence an organization has with sensitive data being housed in an environment outside the organization's direct control and whether or not the organization has the infrastructure and expertise to maintain the physical infrastructure necessary to run an on-site LMS. Cloud-based LMSs are usually proprietary systems where the vendor packages the system functionality with the online hosting of the client's data and then charges a fee for the service based on the number of users accessing the LMS site.

The Future of LMSs

As technology evolves and teaching methods become more student-focussed, the LMS of the future will become more than a helpful administrative tool. As improvements in bandwidth, storage, and mobile device computing capacity expand, the capabilities of LMSs will adapt to fill emerging client demands. LMSs should also be supported by an institutional structure

that promotes an equitable learning environment (Chugh et al. 2017). The general trend of LMS systems is to expand learner interactions with course content by including the capability for users to use mobile devices such as smartphones and wearables such as smart watches and smart glasses. Future developments in LMS technology are also likely to include more sophisticated tools to enable genuine synchronous communication, such as videoconferencing apps and peer-to-peer messaging. Below is a list of enhancements to watch out for in future versions of LMSs.

Cloud-Like Functionality

There is already a trend toward cloud-hosted proprietary LMSs as vendors target their offerings to client organizations that do not have the infrastructure or personnel to manage in-house hosting. However, open-source systems such as Moodle are also evolving to accommodate the possibility of their systems existing solely in web hosting environments. For example, a service such as Softaculous can be used to install and configure open-source apps such as Moodle, directly into the client web hosting account.

Adaptive Learning

Adaptive learning technologies permit course designers to tailor learning tasks and materials to individual learner requirements. Examples of the use of these technologies could include the release of learning content based on prior learner assessment, tailored knowledge tests that focus on learning gaps of each individual student, and the incorporation of learner-created content into each learner's portfolio.

Microlearning with LMSs Connected Devices

Microlearning is an approach to education that delivers content to learners in small, very specific pieces. The learners are given control of when and what they will learn. By creating bite-sized training modules within LMS systems accessible to learners on demand, it will be possible for clients to create their own curriculum tailored to their specific requirements. According to Tauber and Wang-Audia (2014, 10):

1% of a typical workweek is all employees typically to focus on training and development.

The microlearning approach to training delivery is therefore likely to prove popular for workers operating under tight time constraints.

Analytical Tools

Reporting functions which have a descriptive purpose such as enrolment reports, assignment submissions, and user access frequency are already standard features of many LMSs. The challenge for future systems is to tap into the rich and diverse data collected by LMSs and use this information to predict problems and opportunities that may arise. For example, most institutions are concerned about attrition and would appreciate being alerted to circumstances that may lead to a student's failure or voluntary withdrawal.

Social Capabilities

The attraction to formal learning for most students in classroom-based environments is not only the knowledge and skills to be acquired but also the social dimension of study that participation in higher learning provides. LMSs have often been criticized for not adequately accommodating this innate learner need. The inclusion of more synchronous communication tools such as live videoconferencing and real-time social media apps is likely to strengthen the appeal of online learning as a social activity. LMS vendors are already tapping into existing social media apps such as Facebook, Twitter, and WhatsApp along with videoconferencing tools such as Skype to provide a social framework for online learners.

Gamification

Learning games, if structured correctly, can provide a fun and stimulating way to engage learners by rewarding their progress. Future gaming features of LMSs could assign certificates or badges to learners based on their mastery of course content and could even be used to assign a rank or status to individual learners that could be shared within the user community.

Conclusion

Learning management systems (LMSs) have evolved in response to the demand for innovative educational products that leverage advances in information technology and telecommunications. LMSs can be either proprietary, where the client pays for the installation, maintenance, and end-user licensing, or open source, where the source code is freely available but the installation and maintenance is handled in-house. LMSs have many features that support online learning including course management, assessment, learner progress tracking, gradebook, communications, security, and smartphone access. LMSs continue to evolve, and future versions are likely to include tools and features that facilitate more tailored content to individual learners, enhance social interactions between online learners, and provide more timely and relevant analytics to institutional decision-makers.

Cross-References

- ▶ [Blending Learning Provision for Higher Education, Integrating “New Ways” of Teaching and Learning](#)
- ▶ [Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption](#)
- ▶ [Computer-Based Training and School ICT Adoption, A Sociocultural Perspective](#)
- ▶ [Digital Technologies in Higher Education, Learning Challenges](#)
- ▶ [Mobile Learning and Ubiquitous Learning](#)
- ▶ [MOOCs, Teacher Professional Learning and Deep Learning Conversations](#)
- ▶ [Predicting ICT skills and ICT use of university students](#)
- ▶ [Technological Innovation in ICT for Education](#)

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Learning Outcome

► Competency Models in Computing Education

Learning Programming

► Learning Programming, Success Factors

Learning Programming, Student Motivation

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Student motivations have been extensively researched in general education; however, the topic has only been recently investigated in the

context of learning programming. The major themes emerging from current research are:

- Motivational factors are generally intrinsic or extrinsic.
- How relevant students see their learning to their future careers can influence their efforts.
- Some students are independent learners while others want to be taught.
- Self-efficacy can influence the learning effort.
- Students with growth mindsets are more likely to learn than those with fixed mindsets.
- How students react emotionally to their learning can also be an influence.

Motivational Factors

Motivation is a student's "willingness, need, desire and compulsion to participate in and be successful in the learning process" (Bomia et al. 1997). Motivational factors have been categorized into two broad groups: intrinsic and extrinsic.

Intrinsic motivation, also known as self-motivation, is the deep desire for learning of a subject area. It originates from within the person and is influenced by one's self-esteem, self-satisfaction, personal values, needs, and drives (Bomia et al. 1997; Jenkins 2001). It leads to a deeper learning approach and greater conceptual understanding and produces learning outcomes which are flexible and transferable (Entwistle 1998; Vansteenkiste et al. 2006).

With extrinsic motivation, behaviors are performed to satisfy an external demand or obtain an externally imposed reward. They may be done for their instrumental value and not merely for the enjoyment of the activity itself or for its intrinsic interest. Ryan and Deci (2000) describe a continuum of extrinsic motivations, where the motivation varies depending on the degree to which it is autonomous or self-determined. Five types of extrinsic motivation are described:

- *Amotivation (unwillingness)*: lack of an intention to act which may be from not valuing the activity, not feeling competent to do it, or not believing it will yield a desired outcome.

- *External regulation (passive compliance)*: behaviors are performed to satisfy an external demand or obtain an externally imposed reward.
- *Introjection*: behaviors are performed under pressure to avoid guilt or improve self-esteem.
- *Identification*: the person has identified the value of performing an activity and therefore has accepted its regulation as his or her own.
- *Integrated regulation*: the reasons for performing an action are further internalized and integrated to the self and become self-determined.

The stronger forms of extrinsic motivation involve a degree of autonomy with a feeling of choice and a sense of conviction, where subjects display an “attitude of willingness.” Weaker forms involve a mere compliance or external control where subjects are “externally propelled into action.” These weaker forms lead to a surface approach to learning and fear of failure and produce learning outcomes which are inflexible and not readily transferable (Entwistle 1998). Perceived competence, understanding, and the belief of possessing the skills to succeed help to internalize an extrinsic goal (Ryan and Deci 2000).

Other forms of extrinsic motivation include social motivation, which is based on the idea that the primary motivator is the desire to please some third party whose opinion is valued (Jenkins 2001). To some extent, social motivation might include fear of failure as a motivator (Biggs and Tang 2007).

Achievement motivation is based on the idea of doing well for personal satisfaction (Entwistle 1998). The student will adopt whatever strategy they believe will allow them to obtain the best results or highest marks (Jenkins 2001). Entwistle (1998) describes achievement motivation as being:

- Competitive, with the possibility of becoming egotistical and selfish
- Dependent on time management and organized studying
- Treating tasks as personal challenges

Within the context of learning programming, several studies have found that for most

programming students, achievement and extrinsic motivations were the dominant influences on their attitudes toward their studies (Jenkins 2001; Kori et al. 2016). Intrinsically motivated students, however, have been found to obtain higher programming results (Bergin and Reilly 2005a). Furthermore, students who have high levels of intrinsic motivation and task value use more meta-cognitive and resource management strategies (Bergin and Reilly 2005b; Bergin et al. 2005; Sheard et al. 2009). Attempts at using extrinsic motivations in teaching, such as rewards and student comparisons, seemed to have little impact on performance (Bergin and Reilly 2005a).

Several studies have looked at influences on motivation. Lack of skills when learning programming can cause motivation to change from intrinsic to extrinsic, while the presence of skills can increase motivation (Carbone 2007; Carbone et al. 2009). Multimedia arts students doing programming did not have a negative attitude to programming but did expect it to be difficult (Bennedsen 2003).

A number of studies have looked at using different technologies to motivate students to learn introductory programming. The use of digital badges in a Moodle-based introductory programming learning environment was found to be positive, although motivation levels varied among learners and over time (Facey-Shaw et al. 2015). Another study explored the use of mobile technology and social media as tools to support student interactions among themselves in their learning of programming (Maleko et al. 2012, 2014). Other studies have looked at using gamification-based learning platforms to motivate the learning of programming (Burguillo 2010; Fotaris et al. 2016; Swacha and Baszuro 2013).

Career Relevance

General educational research has shown that “when students see the relevance of what they are learning to solve problems and achieve tasks in the real world, especially in desirable occupations, students are more motivated to learn the material and are more engaged in school”

(Woolley et al. 2013). Relevance as a teaching strategy was found to promote a higher engagement and academic achievement (Keller 1987; Means et al. 1997). Studies on expectancy-value theories of motivation have found that the students' perception of the value of the lesson content is a key motivational factor because it influences the student use of cognitive and organizational strategies (Means et al. 1997; Pintrich 1999).

Learning interest orientations can be extrinsic such as students aiming to obtain a qualification which would lead to a job or intrinsic such as students seeking knowledge which would equip them well for their future careers (Beatty et al. 1997; Jenkins 2001). Even when students recognize what they are learning is relevant to their long-term future careers, however, they still may only be motivated to study content that is perceived to be immediately relevant (Lucas 2001). Career motivation and personal interest can coexist and mutually reinforce each other (Kember 2016).

How programming students see programming as relevant to their future careers may influence their motivation to learn programming. This topic, however, has not been extensively explored. Programming has traditionally been taught in Computer Science, where students are usually attracted to programming and intend to work in the IT field (Kinnunen et al. 2016).

A number of studies, however, have found that not all programming students necessarily want to become programmers. Curzon and Rix (1998) found that even students taking a second or third programming module viewed programming as "useful career-wise but only as a secondary skill." Another study found that some first year CS students described their future career plans as the desire to work in their own company, in small start-ups or as managers, rather than in a technical role (Kinnunen et al. 2016).

In a study of engineering students, some students were categorized as "conversational programmers," who did not necessarily want to be professional programmers but wanted to learn programming so that they could "speak the language and improve their perceived job marketability in the software industry" (Chilana et al.

2015). Even non-CS majors who enjoyed learning programming were found to dismiss it as not being applicable to their goals (Hewner and Guzdial 2008).

In a study of what motivates IT students to persist with their degree program, three factors were identified: previous personal contact with IT, the reputation of the IT field, and development (self-development and IT skills development) (Korii et al. 2016).

Various attempts have been made to change programming content and/or use technologies to make learning of programming more relevant to students. Games and web programming were used to illustrate how programming is a relevant skill that is used to solve real-world problems that the students perceive important to have for their future careers (Feldgen and Clua 2004).

A number of studies have attempted to teach programming with LEGO Mindstorms, with mixed results. McWhorter and O'Connor (2009) found that students were more motivated, but mostly for the content rather than relevance. Lykke et al. (2014) also found students more motivated and engaged, but they experienced frustration due to limitations of the robots.

With programming now being taught to a much wider range of students, a deeper understanding is needed of how these students perceive programming as relevant to their careers and how that influences their motivations.

Independence

The approach students take to their own learning has been described in various studies, mostly from the perspective of active/independent learning or passive/dependent learning.

Dependence has been described by Baird and Mitchell (1991) as a poor learning tendency where the learner, despite being keen to succeed, adopts a passive, dependent approach to learning. The learner assumes the role of "a passive recipient of information and instructions," expecting the teacher (or text) to tell them what to do and how to do it (Baird and Mitchell 1991; Carbone 2007).

In a study of programming students, dependence was highlighted as a deficit in generic skills by Carbone et al. (2009). When students got stuck, they sought assistance from experienced friends and tended to act on their suggestions, regardless of whether they had understood or not. One study that investigated student programming success from the instructor's perspective reported that teachers believe that success hinges on students taking responsibility for their learning and putting in sufficient effort (Kinnunen et al. 2007).

A model of "ownership of learning" is presented by Conley and French (2014) in their study of college readiness of students. "Students who own their own learning can go beyond simply following teacher directions. They are more likely to complete complex assignments, solve problems that require persistence, and create original or novel work of high quality" (Conley 2014; Conley and French 2014).

The Conley and French (2014) model of ownership of learning consists of:

- *Motivation and engagement*: Self-guided actions where the students see value in the coursework, are motivated to excel, are interested in the content, and enjoy a challenge.
 - *Goal orientation and self-direction*: Strategies to set academic goals and identify the resources and steps to attain them. This relies on the ability to exercise control over one's behavior.
 - *Self-efficacy and self-confidence*: Students' confidence in their ability to complete increasingly challenging and complex academic and career tasks.
 - *Metacognition and self-monitoring*: Awareness of the learning process, active participation in the learning, and reflecting on that participation.
 - *Persistence*: Related to resilience but also encompasses the notions of grit and academic tenacity.
- In a study of undergraduate student approaches in peer-led workshops in science, engineering, technology, and mathematics, three approaches to learning were identified (Micari and Light 2009):
- *Reliance* – Thinking about getting through the course:
 - Intentions: Reducing anxiety and confusion and gaining confidence and clarity
 - Constraints: Lack of confidence, self-discipline, and time management skills
 - *Engagement* – Thinking about engaging with the material:
 - Intentions: Reducing passivity and increasing involvement, applying rather than absorbing
 - Constraints: Watching rather than doing, knowing principles but not knowing how to apply them, only attempting basic problems, more help is required
 - *Independence* – Thinking about how to learn:
 - Intentions: Becoming a better learner, developing an integrated system for understanding
 - Constraints: Limited set of problem-solving tools, concepts stand alone
- Self-regulated learning (SRL) has been an important topic in the fields of education and psychology. SRL is defined as the degree to which learners are metacognitively, motivationally, and behaviorally active participants in their own learning (Zimmerman 2002). Studies have found SRL to have a significant positive correlation with academic achievement in elementary, high school, and college students (Bergin and Reilly 2006). One model of self-regulated learning includes the following components (Pintrich 1999):
- *Cognitive learning strategies*: include rehearsal, elaboration, and organizational strategies
 - *Metacognitive and self-regulatory strategies*:
 - Planning strategies – setting goals for studying and doing task analysis of the problem
 - Monitoring strategies – monitoring of comprehension using self-testing techniques
 - Regulation strategies – realign back to the goal when the learner realizes a breakdown in understanding, e.g., going back and rereading the text that is not understood.
 - *Resource management strategies*: controlling their time, effort, study environment, and other people such as peers and teachers through help-seeking strategies

- *Motivational beliefs*: include self-efficacy beliefs, task value beliefs, and goal orientations

The cognitive and metacognitive strategies represent the “skill” component, and the motivational beliefs represent the “will” component (Bergin and Reilly 2006).

Students who perform well in programming were found to use more meta-cognitive and resource management strategies than the lower-performing students (Bergin et al. 2005). Ott et al. (2015) attempted to improve student’s self-regulation during their learning by supplying them performance indicators at different stages of an introductory programming course. They found, however, that the students’ study behavior and learning outcome remained unaffected, despite them valuing the information.

In a study by Sheard et al. (2013), students described a range of independence in their learning behaviors and willingness to take responsibility for their own learning. Most students described some degree of independence by expressing a desire to work alone and understand better by themselves. In contrast, other students described a desire to be taught, while one student expressed preference for the type of teaching experienced in high school where students rely on their teachers (Sheard et al. 2013).

Self-Efficacy

Self-efficacy is a person’s perception of their own ability to succeed in a performance situation. Self-efficacy theory has been used as a tool to understand and promote intrinsic motivation (Bandura 1997, 2002). “A person who perceives themselves to have a low-level of self-efficacy will, despite having the necessary potential, ability and skill, not perform well at carrying out a task” (Bomia et al. 1997). Self-efficacy beliefs influence the choices a person makes, such as the degree of effort spent on a task, the level of persistence, and the response to obstacles (Bomia et al. 1997; Wiedenbeck et al. 2004).

There are four principal influences on self-efficacy (Bandura 1997, 2006; Lin 2016):

- *Mastery Experiences*: Repeated successes increase self-efficacy, while repeated failures reduce it.
- *Vicarious Experiences*: Observing similar peers succeed can increase expectations of success.
- *Social Persuasion*: If an individual is persuaded, they can complete a task and try harder.
- *Physiological State*: Levels of stress, tension, fatigue, mood, pain, etc. can impact self-efficacy.

Within the programming education context, a considerable number of studies have found a positive correlation between a student’s self-efficacy of programming and their performance in programming courses (Adair and Jaeger 2011; Altun and Mazman 2015; Bergin and Reilly 2005a, b, 2006; Gomes et al. 2012; Kanaparan 2016; Özmen and Altun 2014). In general, students who feel capable of writing programs tend to perform well, while students who feel they are not capable of writing programs perform poorly.

Similarly, studies have found a correlation between “comfort level” and performance (Cantwell-Wilson and Shrock 2001; Ventura 2005). Students that feel comfortable with their studies will perform better, while students who feel anxiety about learning programming will fare worse.

A number of factors have been found to influence self-efficacy, which in turn influences performance. Several studies have found that previous programming experience is linked to programming self-efficacy (Özmen and Altun 2014; Wiedenbeck 2005; Wiedenbeck et al. 2004). Another found that persistence levels had a significant effect on a student’s self-efficacy beliefs (Lin 2016). Students may also use comparisons with their classmates as a base for their self-efficacy perceptions (Kinnunen and Simon 2011).

Several studies have looked at gender influences on self-efficacy, with mixed results. Lin (2016) found no significant differences in self-efficacy between genders, while Beckwith et al. (2005) found females exhibited lower self-efficacy. Female students have also been found

to revise their self-efficacy beliefs earlier than males, which suggests early failures could cause female students to disengage from their studies (Lishinski et al. 2016).

Variations in self-efficacy have also been studied. Wiedenbeck et al. (2004) found that self-efficacy does increase substantially during an introductory programming course. Changes, however, are also not always straightforward. Students may reflect negatively on their self-efficacy after successfully completing an assignment or positively after struggling with an assignment (Kinnunen and Simon 2011, 2012).

Mindset

Mindset Theory has been developed by Dwek (2008), and others, over the past two decades and describes how a person's belief about their ability influences their response toward a goal (Cutts et al. 2010; Diener and Dweck 1980; Dweck 2000; Elliott and Dweck 1988; Robins and Pals 2002). Dwek (2008) describes two mindset frameworks:

- *Fixed Mindset (learnt helplessness)*

Failures are overestimated and seen as unavoidable, recurring, and unconquerable. Intelligence is seen as static so effort is placed in appearing smart rather developing skills. Failure is viewed as resulting from lack of intelligence with decreasing self-esteem, and the response to setbacks is to give up. The judgment of others and self is seen as important (Diener and Dweck 1980; Dwek 2008).

- *Growth Mindset (mastery orientation)*

Failures are seen as conquerable and avoidable and successes replicable. Intelligence can be developed, so effort and time are spent on developing skills. Failure is attributed to lack of effort, thus maintaining self-esteem. Learning and helping others learn are important (Diener and Dweck 1980; Dwek 2008).

Fixed mindset learners adopt performance-oriented goals, while growth mindset learners adopt learning-oriented goals (Elliott and Dweck 1988).

The learning tendencies of each type of mindset are summarized in Table 1 (Dwek 2008):

A number of studies have recognized the importance of self-theories (mindset) research and how this relates to and impacts the learning of programming. Programming students are confronted with an excessive amount of challenges and negative feedback when learning to program for the first time. Students with fixed mindsets are likely to adopt a helpless response to these innate challenges and view difficulties as a lack of ability or intelligence and disengage by practicing “risk avoidance and strategy abandonment” (Murphy and Thomas 2008).

A study by Cutts et al. (2010) implemented several mindset-based interventions: “tutors taught mindset to students; growth mindset feedback messages were given to students on their work; and, when stuck, students were encouraged to use a crib sheet with pathways to solve problems.” They found that these changes resulted in a significant change in mindset and improvement in test scores. They did recommend that since programming students come up against failure more often than in other subjects, the mindset message may need to be reinforced regularly (Cutts et al. 2010).

Hanks et al. (2009) asked students what advice they would give to future students to develop their growth mindset toward programming. Some of the advice noted by students included:

Learning Programming, Student Motivation, Table 1 Fixed and growth mindset tendencies (Dwek 2008)

	Growth mindset tendencies	Fixed mindset tendencies
Challenges	Are embraced	Are avoided
Obstacles	Are opportunities to learn and persist through	Acts defensive or gives up easily
Effort	Is a path to mastery	Is viewed as fruitless
Criticism	All criticism is constructive, to be learnt from	Perceived as negative, ignored even if useful
Success of others	Offer lessons and inspirations	Feels threatened by it
Result	Reach “ever-higher” levels of achievement	Plateaus early achieving below full potential

- *Make the most of the class*: Clear doubts immediately and get help when you need it. It is very hard to catch up in programming if you fall behind. Programming is cumulative.
- *Learn from mistakes*: The key to understanding is using each error as a stepping stone to learn and understand why the error occurred. “Everybody makes mistakes – learn from them.”
- *Learn from others*: “if you cannot work out your mistake, find someone to help you, or discuss with your friends.”
- *You have to program to learn*: “After solving a problem, change the code and play around with it. Experimenting is the best way to learn.”
- *Have a plan*: (1) “Read through the descriptions of the program, and make sure you know what you are supposed to do”. (2) Make a flow chart. (3) Write the program step by step.
- *Don’t be intimidated*: “Don’t be afraid of asking questions in class” – “Do not worry about looking stupid for not knowing” – “other students may be wondering the same thing”
- *Programming can be fun*: Learning programming is a challenge but also an opportunity. Programming is fun when you start to know it (Hanks et al. 2009).

Mindsets may also be domain specific. Scott and Ghinea (2014) found that students’ mindset for programming aptitude was different to their mindset about intelligence. Educators, therefore, should focus specifically on promoting growth mindsets for programming.

Studies have also looked at the relationship between self-theories (mindsets) with resilience and grit (passion and perseverance to pursue a goal over a period of years). Mindsets have been found to influence resilience (Scott and Ghinea 2014; Yeager and Dweck 2012). A study of high school students by Kench et al. (2016) found a weak correlation between mindset and grit.

Emotions

Some recent studies have tried to understand student emotional experiences when learning to

program. A study by Kinnunen and Simon (2010) investigated students’ emotional experience with and reactions to programming assignments. They identified emotions at six stages of the programming experience:

- *Getting started*: “It’s Greek to me,” “OK, what now?”
- *Encountering difficulties*: Hit by lightning experience, rapid change experience.
- *Dealing with difficulties*: Feedback-guided experience, Hamster wheel experience, course-specific experience, other computing factors experience.
- *Overarching*: Life outside this assignment experience, helping others experience.
- *Auxiliary emotional load*: Impact of outside factors.
- *Self-efficacy experience*: At all stages, there were emotional consequences from students assessing their ability compared to others or to academic success.

One category highlighted in their findings was the “hit by lightning” experience, which they labelled as the mark of the utter novice. This is where a student encounters a problem that comes out of blue, impacts their confidence, and leaves them with little idea of what is wrong or how to fix it (Kinnunen and Simon 2010).

Bosch et al. (2013) got students to self-report their emotions during programming learning sessions. They found that the most common emotions students experienced were flow/engaged (23%), confusion (22%), frustration (14%), and boredom (12%). On the other hand, curiosity, happiness, anxiety, surprise, anger, disgust, and fear were rare. Chetty and van der Westhuizen (2013) found that novice students experience strong oscillating emotions while learning to program, especially when learning threshold concepts.

Summary

Recent research into programming student motivations has given important insights, but more exploration is necessary. With programming now

being taught to a much wider range of students, a deeper understanding is needed of how these students perceive programming as relevant to their careers and how that influences their motivations. With much of the learning now happening beyond the classroom, a deeper understanding is also needed of how independent and dependant learning impacts student learning of programming.

Cross-References

- [Learning Behaviors in Programming](#)
- [Learning Programming, Success Factors](#)

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Learning Programming, Success Factors

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Synonyms

[Cognitive styles in programming](#); [Demographics](#); [Learning influences](#); [Learning influences in programming](#); [Learning programming](#); [Literature review](#); [Previous programming experience](#); [Previous studies](#); [Success factors](#)

There has been considerable research in computer science education looking at factors that impact on students' performance in introductory programming courses. Researchers have sought to identify one or more attributes that could be used to predict and/or influence student success in learning to program. The major themes emerging from current research are:

- Cognitive and learning styles
- Programming experience prior to university entrance
- Previous education (such as math scores)
- Stage in degree and degree major
- A range of demographic discriminating factors

Cognitive Styles and Learning Styles

Cognitive styles and personality is defined as the “individual differences in organizing information, and processing both information and experience” (Bishop-Clark 1995). Cognitive styles and personality variables have been studied as factors that may correlate with programming success.

Field independence and high reflectivity have been shown to be positively related to programming achievement (Bishop-Clark 1995). A field independent person is better at identifying and isolating relevant information from a complex situation, imposing their own structure/organization to the material. Field independence should also be encouraged through teaching (Mancy and Reid 2004).

Studies that have looked at the learning styles/cognitive profile groups described by Krause (2000) found that intuitive thinkers have tended to perform better in programming than sensor feelers (Prasad and Fielden 2002; Woszczyński et al. 2004). Intuitive learners use visual memory cues to trigger retention of information. Thinkers like to have concrete evidence or information to make decisions.

Reflective and verbal learning styles outperformed the active visual ones when correlated with programming performance (Allert 2004). “Students who perform well in programming use more meta-cognitive and resource management strategies than lower performing students” (Bergin et al. 2005).

A number of literature reviews looking at cognitive styles and personality traits have found that while studies do show correlations between factors and performance, they are inconsistent in explaining individual differences and offer little predictive power (Bishop-Clark 1995; Robins 2010; Ventura 2005).

As the different programming phases involve different skills, Bishop-Clark (1995) suggested relating cognitive styles to each distinct phase of programming.

Programming Experience Prior to University Entrance

Various studies have found that students with previous programming experience tend to perform better in programming courses than those students with no previous programming knowledge (Cantwell-Wilson and Shrock 2001; Chinn et al. 2010; Gomes and Mendes 2008; Hagan and Markham 2000; Holden and Weeden 2003, 2004, 2006; Kori et al. 2016). The more languages they already know, the better they perform (Hagan and Markham 2000), but the benefit tends to be more on the first programming course than subsequent courses (Holden and Weeden 2004).

A number of studies have found that previous programming experience influences student’s self-efficacy which, in turn, positively influences performance (Özmen and Altun 2014; Wiedenbeck 2005; Wiedenbeck et al. 2004). In particular, Wiedenbeck (2005) suggests that it is the knowledge organization that directly influences success and strengthens post self-efficacy.

Other studies, however, have found little or no correlation between previous programming experience and student grades (Allert 2004; Bergin and Reilly 2006; Bergin et al. 2005; Murphy et al. 2006; Pillay and Jugoo 2005; Ventura 2005; Ventura and Ramamurthy 2004).

On the whole, previous studies have shown that students with previous programming experience will tend to perform better in learning programming than students with no previous experience.

Previous Studies

A range of previous studies have explored the relationship between grades from high school, or

other previous studies, and student performance in computing degrees, and programming courses in particular. The majority of the focus has been student's previous grades in maths and science, with mixed findings.

A number of studies have found a positive correlation between student's mathematical aptitude and high school scores in maths/science with their performance in programming courses (Altun and Mazman 2015; Bergin and Reilly 2005, 2006; Byrne and Lyons 2001; Cantwell-Wilson and Shrock 2001). Other studies found high school math grades to be a clear moderate positive indicator of success in first year programming courses (Bennedsen and Caspersen 2005; Gomes and Mendes 2008; Qahmash et al. 2015).

Other studies, however, have found that previous grades have little bearing on success in computer science and programming (Boyle et al. 2002). Ventura (2005) found SAT scores offered little predictive value, and Alexander et al. (2003) reported that while good grades may predict good performance in mathematics units, they found "nothing in entry qualifications to indicate which students will be successful in the study of programming."

Stage in Degree and Degree Major

The majority of studies on learning programming have tended to focus on the first programming courses only (Beise et al. 2003). The studies that have looked at two or more programming courses in the programming sequence suggest that a better understanding of the basic concepts of sequence, iteration, and decision occurs during or by the end of the second course (Gomes and Mendes 2008; Sheard et al. 2009; Tew et al. 2005). The more advanced concepts can then be learnt more easily once students have mastered how to problem solve and have an understanding of basic concepts (Holden and Weeden 2004; Robins 2010).

No correlation has been found between the year level of students and the results of introductory programming courses (Bennedsen and

Caspersen 2005; Rountree et al. 2002). The situation is complicated by non-computing major students doing programming in later years or treating a programming course as a "filler" (Rountree et al. 2002).

Various studies have also looked at degree majors and minors as a potential predictive factor of success. The intended major of computer science students has not been found to be a significant factor in programming learning outcomes (Bennedsen and Caspersen 2005; Rountree et al. 2002).

Computer science majors have been found to have a higher probability of passing the first programming course than information systems majors (Beise et al. 2003). A number of studies have reported that efforts in tailoring programming courses for non-CS majors, such as information systems students, have led to higher pass rates (Forte and Guzdial 2005; Yadin 2014; Yadin and Or-Bach 2008).

Demographics

The influence of gender on programming outcomes has had considerable research interest, and to a lesser extent, age.

Gender

The issue of gender imbalance in the field of computing degrees due to the steady decline of female graduates in this field, particularly in the USA, the UK, and other western countries, has been noted by many studies (Sinclair and Kalvala 2015).

Females, however, have been widely found to perform just as well as males, with many studies finding no correlation between gender and programming learning outcomes (Beise et al. 2003; Bennedsen and Caspersen 2005; Byrne and Lyons 2001; Chinn et al. 2010; Pillay and Jugoo 2005; Rountree et al. 2002; Ventura and Ramamurthy 2004). Although females may start their computing degrees with less previous programming experience than their male counterparts, by the

end of their introductory courses, they catch up, achieving similar levels of mastery of programming concepts as the males (Murphy et al. 2006).

Gender differences have, however, been found in student perceptions and attitudes toward learning programming. Male students have been shown to perceive programming as being easier and have a higher intention to program in the future, compared to female students (Rubio et al. 2015).

Female students have been found to be less confident with their skills (Carter and Jenkins 2001) and less comfortable than male students asking questions in class and interacting with their instructor (Alvarado et al. 2017; Sinclair and Kalvala 2015). These differences were even found to be consistent or increase across course levels (Alvarado et al. 2017). Female students have also been found to revise their self-efficacy beliefs earlier than males, which suggest early failures could cause female students to disengage from their studies (Lishinski et al. 2016).

Several studies have also found that female students tend to work more with others and study more with their peers, compared to male students (Chinn et al. 2010; Sinclair and Kalvala 2015). Pair programming was found to be beneficial to help female students build their self-confidence toward learning programming (Carter et al. 2011).

Age

Relatively few studies have looked at student age as a predictor of programming success (Rountree et al. 2002). Those that have studied it have looked at age in combination with other factors and have found that it was not a good predictor of success in programming learning outcomes (Beise et al. 2003; Bergin and Reilly 2005; Rountree et al. 2004; Woszczynski et al. 2005a; Woszczynski et al. 2005b).

Other Factors

Various studies have looked at a wide range of other factors as potential predictors of success in

learning programming. Some of these have included:

- *Involvement in Computer and Video Gaming* was found to be a negative influence on success (Allert 2004; Cantwell-Wilson and Shrock 2001).
- *Attribution to Luck* was also a negative influence (Cantwell-Wilson and Shrock 2001).
- *Resource Management Strategies* are a positive influence (Bergin and Reilly 2005)
- *The Grade the Student Expected to Achieve* at the beginning of the course was the strongest single factor indicative of success (Rountree et al. 2002).
- *The Student's Perception of Their Understanding* of the module was strongly correlated with performance (Bergin and Reilly 2005).
- *Ability to Articulate an Algorithm* in depth and map-drawing style (Simon et al. 2006).
- *Abstraction Ability* had conflicting findings (Sheard et al. 2009). Bennedssen and Caspersen (2008) found no correlation, while Murphy et al. (2005) found that better performing students are more able to express abstract concepts. Students have also been found to think more abstractly as they progress through their programming course (Perrenet and Kaasenbrood 2006).
- *Programming Behaviour Based on Event Pairing* from compilation log data during lab classes showed strong correlation with programming performance (Watson et al. 2014).

Summary

Despite considerable research into success factors over many years, no single factor has been found to provide a clear determinant of success. The experience students go through in learning programming is complex and needs to be studied in depth. The real picture is best summarized by Sheard et al. (2009): “given enough time, clear direction, and instruction, students will succeed in programming.”

Cross-References

- [Learning Behaviors in Programming](#)
- [Learning Programming, Student Motivation](#)

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Learning Resource

- [Indications for Kinesthetic Learning Through Haptic Devices](#)

Learning Strategies and Achievement of IT Students in Higher Education

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Introduction

Lecturers are always intrigued with how and what students learn inside and outside the classroom. This is essential to make sure that students are actively engaged in learning inside the classroom and in comprehending the whole session. As a complement, it is also as important to know students' ways of learning at home. One stream of research argues that any student employing cognitive strategies and organizing her or himself at a high level would have a direct impact on their achievements (Ersözülü 2010). Cabi and Yalcinalp (2012) highlighted that students' awareness about their own styles and their ability to choose and use the most appropriate strategies for themselves are two important factors for their success. In this regard, students need to develop sound strategies to increase their learning effectiveness and to excel (Zimmerman 1994) and be an independent learner as well (Ersözülü 2010). In their review of the literature, Beckers et al. (2016) reported that modern students are supposed to be self-directed learners, learn how to build and use networks,

cooperate with others, and use information and communication technology (ICT) to find appropriate information. More recently, the term STEM emerged to denote for a curriculum based on science, technology, engineering, and mathematics teaching in an interdisciplinary and integrated manner. This further aggravates the learning process for the learner. Thus, the challenging task of identifying the different predictors of academic performance could shed more light into the learning process (Mitrofanu and Iona 2013). Learning strategies can be defined as "behaviors and thoughts in which a learner engages and which are intended to influence the learner's encoding process" (Michou et al. 2013: 3). They are perceived as a schematic structure in the form of a chain of learning activities performed by the learner to get hold of new information (Ersözülü 2010), thus affecting the way a learner selects, acquires, organizes, or integrates new knowledge (Weinstein and Mayer 1983). Strategy is like an arrangement to achieve something or employment of a plan that is developed to reach a goal (Zimmerman 1994). Teachers attempt to teach students what and how to learn, remember, think, and motivate themselves (Weinstein and Mayer 1983). Thus, learning strategies cover both cognitive and metacognitive and affective strategies (Ersözülü 2010). Therefore, it is important to know what drives learning. Those are the features that keep students continue working to fulfill their objectives (Lynn 2009).

In a review of the literature (Lynn 2009), the following implications were highlighted. Initially, meeting the diverse needs of different higher-education students in general and STEM students more specifically represents a challenge for teachers. Secondly, the introduction of technological tools in education did help but in part as identifying students' individual differences, and their learning needs should come first. Stemming from these perspectives, this research is interested in focusing at different learning strategies and explaining their impact on IT student learning. It is clear that this topic is vast and spans different

contexts and disciplines. Accordingly, the following research question is posited: *how can UAEU IT students acquire lifelong effective learning strategies*. This leads to the following sub-questions and expected objectives:

- i. What are the possible impacting factors or models of student learning strategies?
- ii. How those factors impact IT student learning strategies.
- iii. How to help UAEU IT students enhance their learning strategies.

Thus, the purpose of this research is to identify the different learning strategies followed by students. Then the research will discuss the importance of such strategies as applied on UAEU IT students. We leave the comparison between the research findings and other non-IT students to a future research that will follow the current phase. Hence, the term students or UAEU students is used henceforth to denote for findings pertaining to UAEU IT students.

Determinants of Learning

Fook and Sidhu (2015) research investigates learning challenges faced by students in higher education. Their findings showed the following eight main learning challenges faced by students in higher education: cognitive challenge, becoming an active learner, coping with reading materials, instructional problem, language barrier, time management, burden of assignments, and culture difference in higher education. Alhija and Nasser (2016) investigated the impact of five teaching dimensions: goals to be achieved, long-term student development, teaching methods, relations with students, and assessment. She indicated that students perceived assessment as the most important of the five teaching dimensions and long-term student development as least important. Only gender and field of study made a salient difference in students' perceptions of good teaching. Fook and Sidhu (2015) suggested that higher learning institutes should emphasize on the construction of knowledge through active interaction between

the lecturer and the students which became a platform for the students to cope up with the learning challenges they were facing in higher education. Cabi and Yalcinalp (2012) highlighted that the learner styles of students are indicated as the total of four fundamental learning types:

1. Accommodator: Participate in real experiences and prefer learning based on exploration and application and searching. They are open to strange ideas.
2. Divergent: They prefer learning by observing real experiences instead of participating in them. They wish the systematic presentation of the knowledge on the related topic.
3. Converger: Details are very important for those individuals, and they try to understand the whole by studying each part first. They learn for the new knowledge first and then apply it. They are not afraid of making mistakes while learning.
4. Assimilator: They prefer structured and systematic knowledge. Presented knowledge must be detailed and structured and must have visual and audio components.

Cabi and Yalcinalp (2012) found that assimilator learning style was the most adopted by students, and gender has no significant effect on learning styles and no apparent significant effect of learning strategies on learning style of students.

According to the literature review in this research, six factors were identified to influence students' learning strategies and their academic achievement (AA).

Student Motivation

Motivation can be considered as student's needs, wants, interests, and desires to participate in the learning process to excel in his/her AA (Lynn 2009). Motivated student shows great desire, drive, or emotion to participate in the learning process, and it is directly related to academic success unless there is a problem with cognitive skills (Lynn 2009). Wolters (1999) found that the importance of motivational self-regulation strategies could be revealed by finding a positive relationship between students' use of these strategies and indicators of

their cognitive engagement, effort, and classroom performance. He contended that models of self-regulated learning may need to be upgraded to include more directly students' purposeful control of their behavior or thinking for the purpose of impacting their effort and tenacity in fulfilling their different tasks. In a review of the literature (Lynn 2009), three main motives of learning emerge, surface (memorizing), deep (understanding), and competitive, where each motive entails adopting a different learning strategy.

Time-Poorness

Time perspective in academia and industry has proved to be a good predictor of students' learning behavior and academic achievement. Time-poor students feel pressurized as they feel they lack the time to complete their learning activities, and this puts high cognitive and metacognitive demands on students (Lynn 2009). They tend to engage in surface rather than deep learning. Managing time has been associated with better learning performance. Many students find themselves unable to spend as much time on their studies because they have part-time or even full-time work and because of family commitments (Lynn 2009). It is not a matter of having more time to finish a lengthy task; rather, utilizing better time management techniques could allow for the completion of the task within adequate time. Such techniques involve making to-do-lists, priority lists, and task to complete daily and dividing the task to smaller pieces (Koçak and Bayır 2009).

Mastery Effort

Effort can be defined as the amount of time spent on studying [1]. Also, effort refers to whether a student tries hard, asks for help, and/or contributes in the class. Studies of student effort propose that the more difficult a task appears, the less likely it is that the student will be motivated to take the task on. However, studies of student effort also propose that effort is linked with achieving well on a task. Therefore, students might be expected to find out what they need to study, study it, and be successful – if they have the ability to do the assigned task, confidence in this ability, and no concern about the task (Graham 2006).

Assessment Focus

Goal focus or assessment focus (Lynn 2009) is defined as information provided by an agent (e.g., teacher, peer, book, parent, self, and experience) regarding what the agent believed was important and what was required by the assessment procedure (Wolters 1999). In this regard, students consider highly the assessment requirements and making sure that in the game of learning, the lecturer holds the key to their success (Lynn 2009). On the other hand, when the teacher clearly specified the assessment requirements, students were more comfortable and focused on signs and other information given by the lecturer about what counts as important material and what would be in the examination. The same researchers believed that achieving what the lecturer wanted is an important strategy for success (Lynn 2009). Assessment focus affects what and how students learn, student motivation, and sense of well-being (Kinga et al. 2012). If used appropriately, assessment could substantially improve learning but that, most of the time, the impact of assessment practices was to limit, and even to reduce, student learning. It was only recently that researchers started to realize that using assessment as an integral part of instruction could improve learning outcomes for students, and at the same time, attempts were made to connect classroom practice to related bodies of research, notably feedback, motivation, attribution, and self-regulated learning (Kinga et al. 2012).

Competitiveness

Competition is a contest between individuals or groups. It arises when two or more parties strive for a goal. The person who wants to win the competition thinks creatively and works for doing the best (Koçak and Bayır 2009). Competitiveness has usually been viewed as a negative trait as it leads to suboptimal outcomes. However, other research indicated that competitiveness may hold different meanings for people from individualist and collectivist cultures. More specifically, some research viewed competition as something that can lead to self-improvement and personal growth (Vedel 2014).

Listening

Sight and sound and touch are considered important in learning (Lynn 2009). Listening is a passive skill that students could acquire spontaneously during classroom activities. In a listening activity, some students like to listen to the text once or twice to understand and hold more information (Bekleyen 2009). In a listening process, the listener must use a wider variety of knowledge sources, linguistic and nonlinguistic, to understand and take the incoming information (Graham 2006).

Case Background

Information about UAE's society [UAEInteract.com]. Information about United Arab Emirates University (UAEU) could be found at UAEU.ac.ae, and the university is located in Al Ain city and was established in 1976 and is the first comprehensive national (federal) university in the United Arab Emirates. Al Ain city is the second largest city in the Emirate of Abu Dhabi and the fourth largest city in the United Arab Emirates. It is located approximately 160 km east of the capital Abu Dhabi and about 120 km south of Dubai. Al Ain has the country's highest number of Emirati nationals.

UAEU has nine colleges. UAEU is currently ranked the number 1 research university among other Gulf countries and number 2 in the Arab World and number 385 globally. The total number of faculty members in the university during the academic year 2013–2014 was 644, in addition to a number of visiting faculty. There were 14,024 students registered at the university during the academic year 2013/2014. Enrolled male students represented 23%, while female students represented 77% of the entire student population.

As UAEU is a federal university, it serves all the Emirates in UAE, but in the past few years, most of the Emirates had their own local and federal universities and institutions, and accordingly, the UAEU coverage started to be limited to few Emirates as the research results show and suggest (below). Due to the considerable distances between the different Emirates and

according to UAE's strong tribal system (culture and traditions) and Islamic beliefs, this puts limitations on the free movement of females. Of course, this is for the sake of protecting and preserving them.

Accordingly, UAEU is pledged to provide complex network of transportation means (UAEU busses and cars and even air transportation) to safely transport male but mostly (larger proportion) female students between Al Ain city and the different Emirates/cities/islands each weekend and during other formal holidays. UAEU provides internal hostels with free full boarding and catering for both male and female students during the academic year. Female students (from outside Al Ain city) inside the hostel are confined to its premises and to the female side of UAEU campus. There is no intermingling between male and female students in the campus, and accordingly, the UAEU campus is split almost identically to separate between male and female sides. However, UAEU provides state-of-the-art social, sporting, and entertainment facilities to enrich the lives of both male and female students.

Findings and Analyses

As shown in Table 1, the majority of respondents came from the College of IT (CIT). The majority of respondents were singles (87%), females

Learning Strategies and Achievement of IT Students in Higher Education, Table 1 Distribution of responses across different colleges in UAEU

College	Frequency	Percent
College of IT	130	72.6
College of Science	20	11.2
College of Engineering	3	1.7
College of Education	1	0.6
College of Humanities and Social Sciences	13	7.3
College of law	2	1.1
College of Business and Economics	9	5.0
College of Medicine and Health Sciences	1	0.6
Total	179	100.0

Learning Strategies and Achievement of IT Students in Higher Education, Table 2 Distribution of responses across different Emirates in UAEU

Emirate	Frequency	Percent
Abu Dhabi and Al Ain cities	71	39.7
Dubai	5	2.8
Sharjah	31	17.3
Ajman	8	4.5
Ras Al Khaimah	27	15.1
Fujairah	36	20.1
Umm Al Quwain	1	0.6
Total	179	100.0

(90%), and UAE citizens (98%), and the remainder were from other Arab origins. Most of the responses came from students in their second (22.3%) third (19.0%), fourth (26.8%), and fifth (13.4%) year in UAEU. All respondents owned a laptop.

As shown in Table 2, the majority of UAE respondents came from the Emirate of Abu Dhabi and Al Ain city (39.7%) followed by Fujairah (20.1%), Sharjah (17.3%), and Ras Al Khaimah (RAK) (15.1%).

Motivation

Motiv3, 4, 5, 6, 7, and 8 (as ordered in Appendix 1) scored relatively the highest in this context (Table 3). This indicates that students resort to reminding themselves about the importance of getting good grades, to push their limits to see if they can do better, work hard in order to learn, try to become good at what they are learning or doing, and study at times when they can be more focused. It is interesting to know about the mechanisms put in place by students in order to act upon such motivating issues. It is also worth investigating whether such views were sporadic or as a result of a continuous effort (i.e., lifelong learning). In the second set of views, it shows that UAEU students try to make university work more enjoyable by focusing on the fun part of it, try to relate the materials to their life activities, and get rid of distractions that arise around them but more at a moderate level.

In line with the above discussions, students had a lower view of the enjoyability of their courses and the detachment of such courses from their

Learning Strategies and Achievement of IT Students in Higher Education, Table 3 Motivation

Item	Mean	Std. deviation
Motiv7	4.30	0.910
Motiv8	4.30	0.934
Motiv4	4.14	0.935
Motiv3	4.14	0.953
Motiv5	4.13	0.956
Motiv6	4.08	1.008
Motiv9	3.82	0.991
Motiv2	3.75	1.036
Motiv1	3.66	1.006
Overall averages	4.04	0.97

Overall, the research findings suggested that UAEU's students are motivated

Learning Strategies and Achievement of IT Students in Higher Education, Table 4 Time-poorness

Item	Mean	Std. deviation
Time1	3.35	1.088
Time2	3.35	1.138
Time3	3.26	1.103
Overall averages	3.32	1.11

Overall, the research findings suggested that UAEU's students are moderately time-poor

real-world settings. This is an interesting contrast between the two sets of views which show a void between what the students learn in the classroom and the outside world. This calls for extending surrogates to what is being taught to students and attempt to link it more with the outside world.

Time-Poorness

The items of this factor scored moderately above the average on the 5-point Likert-scale (Table 4) and hence, agreeing that time-poorness impact their learning negatively. This is due to not having enough time to study, work and family commitments, and not putting sufficient time to understand what they read. It would be interesting to investigate student's teaching load at each semester and whether this load is adequate and balanced or not and also to investigate student's time utilization in studying inside (usually in UAEU's internal hostel) and outside the campus and between students living inside and outside Al Ain city.

It is worth noting that UAE nationals have strong social system and ties, and hence, all members including students are actively engaged in this system.

Mastery Effort

Student responses showed overall modest effort (Table 5). As per the measures, students understand the things that seemed to be difficult at the beginning, are being strict in their studying habits and more dependent on the illustrative course slides than any other learning tools, and understand the assessment requirements earlier on in the course. It is interesting to correlate such items with student's GPA by any future study. On the other hand, students spent less effort on reviewing the additional readings, as suggested by the lecturer; and they did not rely on the prescribed textbooks in studying (Effort2 and 4 scored the lowest). The above contrasts may suggest a separation between students' habits of learning and their actual learning which is limited to the course's slides. For example, students viewing themselves as strict in their studying habits may contradict with the depth level of such studies. This is worth for further investigation by any future research.

Assessment Focus

According to the high scores in Table 6, most UAEU students pay close attention to information that the lecturer provides about exams, they scout out for any hints, and they try to keep in mind exactly what a particular lecturer want when working on assignments. The suggested high

Learning Strategies and Achievement of IT Students in Higher Education, Table 5 Mastery effort

Item	Mean	Std. deviation
Effort7	3.94	0.910
Effort1	3.70	0.988
Effort6	3.60	0.962
Effort5	3.35	1.007
Effort3	3.18	1.124
Effort4	2.97	1.052
Effort2	2.87	1.083
Overall averages	3.37	1.018

Learning Strategies and Achievement of IT Students in Higher Education, Table 6 Assessment focus

Item	Mean	Std. deviation
Focus1	4.30	0.947
Focus4	4.30	0.885
Focus3	4.20	0.978
Focus2	4.12	0.956
Overall averages	4.23	0.942

Learning Strategies and Achievement of IT Students in Higher Education, Table 7 Competitiveness

Item	Mean	Std. deviation
Competi1	4.39	0.889
Competi2	4.08	0.953
Competi3	3.00	1.213
Overall averages	3.82	1.018

assessment driven here such as showing consistent ambitious attitude at the student's side in order to pass and to excel in the different assessments, but according to the above suggested contrasts, may advocate a possible void between what is happening inside and outside the classroom. The fear here is that UAEU students are more concerned with merely passing a corresponding course than learning per se. This predisposition is worth of further investigation as well.

Competitiveness

From the high averages in Table 7, it shows that UAEU students seek to get high grades in their studies to get the best job and see themselves as ambitious. They were almost neutral on prospering financially. Interestingly, being ambitious came after attempting to get high grades and best jobs. Another interesting finding here is that financial incentives were not the main driver to obtain a university degree. These findings are worth for further investigation.

Listening

According to Table 8, the highest scores (Listen3 and 5) showed that students would understand better if the lecturer explains things rather than reading about them and prefer listening to the lecturer than reading textbooks (as endorsed above). This shows a strong propensity by UAEU students

Learning Strategies and Achievement of IT Students in Higher Education, Table 8 Listening

Item	Mean	Std. deviation
Listen5	4.47	0.837
Listen3	3.96	1.054
Listen4	3.58	1.170
Listen1	3.46	0.967
Listen2	3.45	0.961
Overall averages	3.78	0.998

to rely more on the lecturer's explanations than reading the course's textbook. Thus, the listening aspect was more effective if students hear explanations rather than reading the prescribed textbook. It is important to measure students' recollection of what they hear and learn in the classroom by any future research vis-à-vis literature on cognitive capability and absorption capacity. Although listening is important in learning, this is not sufficient to effectively learn and remember the explained material during classroom meetings.

The above discussion about relying on the course's slides and less on the textbook for learning may suggest a weakness in learning in general and their reading capabilities in particular among the surveyed sample. This could be attributed to time-poorness or to weakness in the English language, e.g., a fear or discomfort in reading a large number of English scripts and chapters. These important assertions are worth for further investigations.

Finally, Table 9 shows the overall means of the different items in this research. It could be argued here that overall, assessment focus, motivation, competitiveness, and listening, respectively, were the most important strategies adopted by UAEU students. Time-poorness was not a big problem, but mastery effort needed to be boosted among UAEU students.

Discussion and Conclusion

This research was developed with a focus to understand student learning strategies in UAEU. This research reviewed relevant literature in pedagogy and developed a framework that highlighted important learning strategies. The potential impact of each variable on student's

Learning Strategies and Achievement of IT Students in Higher Education, Table 9 Overall means of the different items

Item	Mean	Std. deviation
Assessment focus	4.23	0.942
Motivation	4.04	0.97
Agreeableness	3.97	0.94
Extraversion	3.87	0.95
Competitiveness	3.82	1.018
Openness	3.78	0.961
Listening	3.78	0.998
Conscientiousness	3.45	1.048
Mastery effort	3.37	1.018
Time-poorness (item worded negatively)	3.32	1.11
Neuroticism (item worded negatively)	2.73	1.196

learning strategies is examined using a survey questionnaire. And Table 10 summarizes the research findings and implications.

This research has theoretical as well professional contributions and contentions. At the professional level, different suggestions were made to enhance students learning strategies within UAEU (Table 10). At the theoretical level, initially, this research generated further insights pertaining to UAEU students' learning habits. Although it was not possible to elucidate the significance of the research factors on student's success as such, the suggested factors and explanations shed interesting insights and contrasts at the same time on UAEU students' learning strategies.

Overall, the research findings suggested that the learning strategies of UAEU students were modest. The highlighted contrasting views and the dominance of most responses around the mean further suggested this posture. This could be attributed to personal as well as to cultural reasons as hypothesized in many parts in this research. Being a lecturer in CIT, one of the researchers admits his bias in suggesting many of the explanations and suggested propositions. Many of the suggested improvements could be achieved by designing programs aiming at enhancing student's learning capabilities and strategies. However, it is the cultural aspects that are more difficult to unveil and address.

Learning Strategies and Achievement of IT Students in Higher Education, Table 10 Research findings and implications

#	Factor	Findings	Implications and suggestions
1	Student motivation	UAEU's students are motivated	In line with the above, adding the enjoyability component into learning in the classroom is important. For example, edutainment emerged as a recent notion to promote learning while playing a game. Capitalize on student motivation issues by coaching students about how to exploit such forces to their learning and excellence through seminars and workshops. Providing links to courses from real-life events (local and international) could assist such students' link theory with practice (i.e., case studies, site visit as integral component of course design) conducting a review of such courses could further help in this regard.
2	Time-poorness	UAEU's students are almost time-poor	It is worth reviewing students' loads each semester and whether they have sufficient time to cover all courses adequately. Providing workshops on time planning and management should warrant against such wastage of time. Endorsing more community bonding should engage the families of students in their learning by freeing them to focus on their studies.
3	Mastery effort	UAEU's students are of modest mastery effort	Capitalize on student eagerness to learn by coaching students about how to exploit such forces to their learning and excellence through seminars and workshops. Encourage the use of other learning material in addition to the course slides. For example, highlight that exams will come from the book, beyond the slides' content.
4	Assessment focus	UAEU's students are more assessment-focused	Capitalize on this factor as one main driver for learning.
5	Competitiveness	UAEU's students are competitive	Attempt to tie self-ambitions with achievements and excellence and financial rewards through training and seminars. This should take place at the beginning of students' enrollment at the university and should be continuously be reminded throughout their academic years.
6	Listening	UAEU's students prefer listening than reading	Encourage reading by boosting the capabilities of students in the English language and maybe through creating reading clubs and/or competitions for reading/writing English texts (i.e., best essay, paper, etc.)

Cultural issues require the cooperation and collaboration of the overall community surrounding learning in general within UAEU in general and the family in particular.

Secondly, as suggested here, it is worth investigating the possible overlap between the different factors in general and between motivation and mastery effort in particular by any future research. For example, the possible interrelationships between motivation and mastery effort may impact learning in a different way as highlighted in this research.

The expected outcome of this research will be of importance to researchers, professionals, and policymakers interested in addressing weak and

strong learning strategies. This is an initial research in this area in UAE, and indeed, other researchers and universities maybe interested to understand the learning strategies of their students. Researchers could further use the suggested factors or add to them and test their significance on their contexts. Professionals would capitalize on many of the implications in this research (Table 10) to design and offer training programs and workshops aimed at students and officials in universities and elsewhere. Policymakers could consider many of the suggestion made in this research to devise effective policies to enhance student learning strategies.

Appendix 1 The Survey Questions

Motivation 1. Make university work enjoyable by focusing on something about it that is fun 2. Try to find ways that the material relates to my life 3. Remind myself about how important it is to get good grades 4. Push myself to see if I can do better than I have done before 5. Persuade myself to work hard just for the sake of learning 6. Challenge myself to complete the work and learn as much as possible 7. Think about trying to become good at what we are learning or doing 8. Try to study at a time when I can be more focused 9. Try to get rid of any distractions that are around me	Time-poorness 1. Don't have enough time to do as much study as I need to for my course 2. Other things such as work and family do not leave me enough time to think about the ideas from my studies 3. Often I don't have enough time to really understand the ideas I read about Assessment focus 1. Pay close attention to information the lecturer gives about exams 2. Lecturers sometimes indicate what is likely to be in the exams, so I look out for hints 3. Take care to find as much information as possible on what will be in an exam 4. When working on an assignment, I try to keep in mind exactly what the particular lecturer seems to want
Mastery effort 1. Try to be strict with myself in my study habits, so that I can do the very best I can 2. Look at most of the additional readings suggested by the lecturer 3. Limit my studying to the slides only 4. Use the prescribed textbook in my study 5. Make sure I clearly understand the assessment requirements early in the course 6. Usually set out to understand thoroughly the meaning of what I am asked to read 7. Usually put a lot of effort into trying to understand things that at first seem difficult	Competitiveness 1. Want high grades in my studies so that I will be able to select from among the best jobs available 2. See myself as an ambitious person 3. The main benefit of a university education is that it will enable me to earn more money Listening 1. Remember best things that are spoken 2. Remember best what I hear 3. Prefer listening to the lecturer than reading textbooks 4. Prefer listening than reading 5. Understand better if the lecturer explains things rather than reading about them

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Learning Theories

► Computing Education, Practices in

Learning Tools

► Adoption of Virtual Laboratories in India, Learning Assessments and Roles of ICT Skill Learning Tools

Learning with Simulations in Healthcare

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Introduction

In the field of healthcare, a strong connection between education and real-life work contexts has been common for a long time. The oldest replications of the real world are anatomical models, part-task trainers, and role-playing (Nehring and Lashley 2009; Rosen 2008), and the medical field was among the first to apply simulation in education (Helle and Säljö 2012). Innovations in other industries, such as

technology and plastics, have made it possible to create more advanced simulators, such as high-fidelity patient simulators, games, and virtual realities (Rosen 2008). In the past two decades, the use of and research into simulation have grown rapidly. The aim of simulation-based healthcare education is to improve the quality of patient care and patient safety (Rall and Dieckmann 2005).

Existing empirical knowledge confirms the effectiveness of simulation-based education (Cook et al. 2011). Numerous studies have also shown that learners enjoy this type of learning (Brewer 2011; Konia and Yao 2013; Weller 2004), because it is learner-centered, experiential, and active learning mode. In addition, learning processes take place in safe environments. Participants can be taught many of the skills needed in working life, including clinical skills (Beauchesne and Douglas 2011) and theoretical knowledge (Chakravarthy et al. 2011), but most importantly with simulations, participants can learn many general competencies, including critical thinking, decision-making, problem-solving, and communication skills (Konia and Yao 2013). These competencies are sometimes even more important and more difficult to learn than basic clinical skills. Finally, simulations may increase learners' self-confidence (Figueroa et al. 2013; Gough et al. 2012; Morgan and Cleave-Hogg 2002; Paskins and Peile 2010).

Despite the acknowledged benefits of simulation-based education, challenges and the need for pedagogical development exist. Learning with simulations can be expensive and time-consuming depending on how it is conducted (Zigmont et al. 2011a). The facilitator must also have many competencies, including sufficient content-related and pedagogical knowledge (Keskitalo 2011), thus, placing high demands for appropriate simulation instructor training. In addition, it is not quite clear how simulation-based education should be realized in practice in a pedagogically sound way (McGaghie et al. 2010), as the underlying teaching and learning processes that lead to learning are not yet known. However, the strength of learning with simulations is the ability to provide meaningful learning experiences for participants (Keskitalo 2015) and, of

course, to support their learning and professional development (Cook et al. 2011).

Simulations in Healthcare Education

Within medical and healthcare education, many concepts refer to different types of simulations. Simulation is an umbrella term, which can be perceived as anything from simple verbal role-playing to more complex simulation-based training that involves modern technologies. In the most basic sense, simulation means imitating reality. Within healthcare, this means imitating the physiology or anatomy of the human body or imitating a specific healthcare process. *Role-play* is one of the simplest forms of simulations (Gaba 2004; Nehring and Lashley 2009). While role-playing, learners may practice “stepping into someone else’s shoes”; for example, a surgeon and a nurse may change roles and experience different perspectives of the same situation. The term *simulator* refers to a specific technical device (e.g., a mannequin or a screen) that attempts to mimic reality and that enables the simulation (Rall and Dieckmann 2005). In the healthcare field, the term usually refers to *human patient simulators* (also referred to as mannequins, computer patients, mannequin-based simulators, or integrated simulators) that vary in fidelity, in other words, in their ability to simulate reality (Maran and Glavin 2003; Nehring and Lashley 2009; Ziv et al. 2000). Simulators are operated (e.g., by a simulation operator or a facilitator) with a computer, which allows participants to interact with the “patient” as they would in a real clinical environment. Other types of simulations include *part-task trainers* or *task trainers*, simulators that imitate certain body parts. Part-task trainers are usually used for learning a particular task or skill (Maran and Glavin 2003; Nehring and Lashley 2009).

A *simulation scenario* is an experience-based episode, designed around a specific healthcare problem or a task. This scenario usually involves a patient simulator, simulation room, medical equipment, and role players (Dieckmann et al. 2007b). In situ *simulations* are the most realistic

forms of simulation, in which learners may practice with their real colleagues and with real equipment in a real environment (Gaba 2004). A *computer simulation* (also referred as screen-based simulation, screen-based simulator, or computer-based system) is learning with an artificial reality that is created using a computer (Alinier 2007). In a computer simulation, individuals interact with a simulated task, environment, or human physiology through a computer interface. *Standardized patients* (also referred as simulated patients or patient actors) are real human beings who are trained to act as real patients (Alinier 2007; Gaba 2004). Standardized patients can have real experience of the disease that is being simulated.

These different types of simulations and devices are usually situated in *simulation centers* (also referred as a simulated environment, a skills laboratory, or a patient simulation center) that are recreations of real work environments (Gaba 2004). Simulation centers can be also viewed as *simulation-based learning environments* (Keskitalo 2015), because they imitate reality for learning purposes. Simulation centers usually have several simulation rooms for different purposes, for example, an operating room, intensive care unit, emergency department, or ward with different types of computer-directed patient simulators mimicking patients of different ages (i.e., adults, children, and infants). There is usually also a separate room (the so-called control room) for the simulation operator and facilitators, as well as a quiet space for the debriefing.

Simulations can also be realized through *virtual realities* or *virtual worlds*. With virtual reality or a virtual reality simulator, the aim is to present a patient or an environment to a user using two- or three-dimensional (3D) virtual objects. Virtual realities are used especially in surgical training to practice procedural skills (Issenberg et al. 2001; Kneebone 2003). Virtual worlds or multi-user virtual environments are 3D shared places, where thousands of participants can simultaneously collaborate with each other via avatars in a noncompetitive manner.

However, as Gaba (2004) pointed out, a simulation is more of a technique than a

technology to replace or amplify real experiences (p. 2). Therefore, the most important factor for successful simulation-based learning is proper pedagogical use of such environments. In the following sections, the theoretical premises and pedagogical principles of simulation-based healthcare education are presented.

Theoretical Premises of Learning with Simulations in Healthcare

The idea of simulation-based learning is rooted in the ideas of andragogy (Knowles et al. 1998; Wang 2011), Kolb's experiential learning (Fanning et al. 2013; Kolb 1984), sociocultural theory (Sadideen and Kneebone 2012; Vygotsky 1978), as well as research on expertise and deliberate practice (Eriksson and Charness 1994; Wang 2011). Recently, the sociomaterial perspective has emerged as a way to understand the learning process within simulation-based learning environments (Fenwick and Dahlgren 2015). These theoretical perspectives underlying simulation-based learning are presented in more detail.

Andragogy (Knowles et al. 1998) can be considered an underlying theory of learning with simulation, focusing on educating adult learners who in this context are healthcare or medical students or professionals already working in the field (Fanning and Gaba 2007; Wang 2011; Zigmont et al. 2011a). The learners' age sets certain prerequisites for pedagogy because, according to Knowles et al. (1998), adult learners differ considerably from children in terms of age, maturity, and life experiences. Previous studies revealed that adult learners tend to be independent and self-directed and feel responsible for their own learning. They are usually internally motivated and value things that are directly applicable and beneficial (Clapper 2010; Wang 2011; Zigmont et al. 2011a). According to Keskitalo (2012), adult learners also have higher expectations for simulation-based education than younger learners do. Therefore, simulation-based education should be timely, convenient, and accessible but perhaps most importantly, learner-centered.

Learning in general (Mann 2011) and with simulations (Dieckmann et al. 2007a; Pasquale 2013) is social and collaborative. Learners interact with each other and with their sociocultural environment to solve a patient case. Therefore, the sociocultural theory of learning (Berragan 2011; Keskitalo 2015; Keskitalo et al. 2014; Paige and Daley 2009; Perkins 2007; Sadideen and Kneebone 2012) and recently, sociomaterial perspectives have been applied to understand simulation-based learning as a social practice (Fenwick and Dahlgren 2015; Nyström et al. 2016). These viewpoints consider learning (Lave and Wenger 1991; Vygotsky 1978), as well as professional practice (Fenwick and Dahlgren 2015; Nyström et al. 2016), as something more than individual processes, and success or failure cannot be regarded as completely dependent on individual performance alone. On the contrary, learning and performance are in constant interplay between individuals and their wider sociocultural context (Lave and Wenger 1991; Nyström et al. 2016; Vygotsky 1978), which is messy and dynamically evolving and where the boundaries of groups and organizations are blurry (Fenwick and Dahlgren 2015). This certainly challenges the interaction and is worthy of further examination.

Kolb's (1984) experiential learning theory is the first pedagogical model implemented in simulation-based healthcare education (Anderson et al. 2008; Fanning et al. 2013; Wang 2011; Zigmont et al. 2011a). Kolb's (1984) learning cycle involves four phases: (1) concrete experience, (2) reflective observation, (3) abstract conceptualization, and (4) active experimentation. Experiences (in this case, simulation) are triggers for learning. During simulation-based learning, an adult learner participates in the simulation, reflects on his or her experience of the simulation during the debriefing, and thereafter, transforms the experiences into knowledge that is usable in a new simulation and ultimately, in future healthcare practice (see Fanning et al. 2013).

Vygotsky's (1978) sociocultural theory and the theory of deliberate practice (Anderson et al. 2008; Ericsson and Charness 1994) have also yielded practical instructional principles

for simulation-based healthcare education. Vygotsky's (1978) zone of proximal development (ZPD) has been adopted in healthcare education as well (Kneebone 2005; Sadideen and Kneebone 2012; Stocker et al. 2014). The ZPD is the area between the actual and potential levels of development. The potential level of development is achievable by more capable peers or a facilitator, whereas the actual level of development can be reached by the learner on his or her own. Each learner also has his or her individual ZPD. Thus, teaching should be based on the competencies that are developing, not the skills and knowledge that the learner already has (Vygotsky 1978). Through a simulation, learners can be exposed to deliberate practice that is required to develop expertise (Anderson et al. 2008; Causer et al. 2014; Issenberg and McGaghie 2002; Konia and Yao 2013; Udani et al. 2014; Wang 2011). Generally, deliberate practice refers to individualized training activities that aim at improving the current performance level with repetition and refinement to reach an expert level (McGaghie et al. 2009). To put these instructional principles together, in simulation-based education, new competencies are learned during collaborative problem-solving tasks with the help of expert facilitators or more capable peers. The facilitator's main task is to diagnose the level at which an individual learner is in his or her knowledge or skills (the ZPD) and to design learning tasks, as well as provide specific, informative, and gradually fading support, as proposed by deliberate practice theory.

Meaningful Learning with Simulation in Healthcare

One of the most recent additions to the field is the pedagogical model for simulation-based healthcare education (Keskitalo 2015); see Fig. 1. This model was developed for simulation-based education by synthesizing existing theoretical knowledge and by conducting empirical studies in the field of healthcare.

The characteristics of meaningful learning form the core theoretical component of the pedagogical model (the 14 characteristics of

meaningful learning situated at the center of the model). The concept of meaningful learning was invented by Ausubel (1968) and later used in various contexts to design, implement, and evaluate education (Jonassen 1995; Keskitalo et al. 2011; Löfström and Nevgi 2007; Ruokamo and Pohjolainen 2000). According to Ausubel et al. (1978), meaningful learning is a process in which new information is assimilated with what the learner already knows during the learning process when the learner engages in the meaningful learning task and materials. Jonassen (1995) developed Ausubel's ideas further, and for him, meaningful learning was active, constructive, collaborative, intentional, conversational, contextualized, and reflective.

Meaningful simulation-based healthcare education should emphasize 14 qualities of meaningful learning (Keskitalo 2015): experiential, experimental, emotional, socio-constructivist, collaborative, active, responsible, reflective, critical, competence-based, contextual, goal-oriented, self-directed, and individual. With these qualities in mind, the facilitator can plan, implement, and evaluate the entire instructional process in order to enhance the quality of the learning experience and to develop even more innovative pedagogical practices. These 14 characteristics of meaningful simulation-based learning are presented below.

Experiential

Previous experiences guide our behavior and learning (Carlson et al. 2010). In addition, during simulation-based education, adult learners use their previous experiences as a starting point and a resource for learning (Kolb 1984; Zigmont et al. 2011a). Therefore, it is important to activate these previous experiences and apply them but also to reflect and reconsider harmful mental models (which may lead to ineffective procedures) through guided self-reflection during the debriefing (Dieckmann et al. 2007b; Wang 2011; Zigmont et al. 2011b).

Experimental

Previous experiences guide our learning, but learning with simulations is also an opportunity to provide new experiences for learners and



Learning with Simulations in Healthcare, Fig. 1 Pedagogical model for simulation-based healthcare education (Keskitalo 2015)

expose them to deliberate practice. Learners have an opportunity to experiment with new tools, devices, situations, roles, theories, etc., before entering the healthcare practice, or professionals can maintain their expertise, or a simulation can be used as a method for testing newly designed devices or processes (Cleave-Hogg and Morgan 2002; Gaba 2004). The simulation facilitator provides the sandbox for learners to experiment widely and at the same time, actively encourages and supports learners.

Emotional

Emotions are intertwined with learning in many ways (Damasio 2001; DeMaria et al. 2010;

Immordino-Yang and Faeth 2010; Schuzt and DeCuir 2002), and simulation-based learning is sometimes purposefully designed to generate emotional experiences in learners. The environment, scenarios, and materials are designed to evoke emotional reactions (DeMaria et al. 2010). The facilitator's role is to set a safe and confidential scene for learning during the beginning of the learning process, as well as take these emotional responses into account afterward.

Socio-constructivist

The aim of simulation-based learning is for learners to participate in the enquiry process and gradually accumulate knowledge about the

patient's condition from their previous knowledge, their peers, the patient's file, and medical investigations, as well as other sources, in order to deliver the correct treatment (Alinier 2011) and to co-construct new knowledge. As a result of this problem-solving process, learners accommodate and co-construct new knowledge based on their previous knowledge and experiences during the collaborative learning process (Dieckmann et al. 2007b; Dolmans et al. 2005; Jonassen 1995; Keskitalo 2012). The environment, tasks, and materials are used to support students' knowledge co-construction; for example, the facilitator creates cases that are based on learners' previous experiences and that require collaboration. The facilitator's main role, however, is to guide learners' collaboration and knowledge co-construction.

Collaborative

Simulation-based learning is designed to be a collaborative undertaking. From the beginning of the learning process, learners participate in the interaction, bringing their knowledge, understanding, experiences, and skills to the joint activity and discussion. The learning goal can be to practice crisis resource management which requires practicing leadership, communication, negotiation, problem-solving, and decision-making skills (Fanning et al. 2013). The facilitator's main role is to facilitate this collaboration and knowledge construction.

Active

The core idea is that learners participate actively during simulation-based learning. Consequently, the facilitator guides rather than lectures (Fanning and Gaba 2007; Issenberg et al. 2005; Jonassen 1995; Keskitalo 2011). The environment, materials, and pre-assignments are designed so that they require learner activity. The facilitator's main role is to plan appropriate cases and encourage learners to take an active role during the whole learning process (Alinier 2011).

Responsible

Adult learners are mature and thus, are responsible for their own learning. Teaching does not lead directly to learning (Kansanen et al. 2000);

instead, teaching is necessary for learners to actively co-construct their own understanding.

Reflective

Reflection on the learning process is often considered the most critical phase of simulation-based learning as it is the place for learners to be able to review their own learning (Alinier 2011; Cook et al. 2011; Dreifuerst 2012; Issenberg et al. 2005). Reflection involves reflecting on one's own learning, learning strategies, knowledge, skills, attitudes, and the learning environment (Fanning and Gaba 2007; Issenberg et al. 2005; Jonassen 1995; Rudolph et al. 2008) but also receiving and giving feedback (Jonassen 1995). The learning environment may include elements that support the learners' reflection (e.g., a video camera, TV, peaceful and pleasant room, safe atmosphere, competent instructor, etc.). In addition, assignments (e.g., a learning diary) can support the reflection. The facilitator supports the students' reflection by asking questions, specifying, elaborating, guiding, etc., that is, by being a "cognitive detective" (Rudolph et al. 2007).

Critical

Being critical is interrelated with the reflective feature of meaningful learning. Being critical in a debriefing is especially important in the field of healthcare where errors can lead to medical mistakes and endanger patient safety in the real clinical environment (Rudolph et al. 2006). Being critical means conducting a debriefing with good judgment as proposed by Rudolph et al. (2006). The facilitator not only critiques but also makes his or her expert view of the situation visible for learners and uses that view as the basis for exploring the learners' sense-making process. Thus, the facilitator's own reasoning becomes part of the debriefing and helps the participants form their own expertise.

Competence-Based

The learning objectives of simulation-based healthcare education should be based on the skills and knowledge needed in real working life (Anema 2010; Harden et al. 1999). This means that content is simulated through real-life cases (Dolmans et al. 2005) and the environment

includes authentic tools and devices (Alinier 2011). An experienced facilitator plans appropriate and sufficiently authentic scenarios and formulates the learning objectives collaboratively with the learners, if possible.

Contextual

Information is best learned when it is taught and practiced in a context that resembles real life (Bransford et al. 1999). The real-life context also enhances the transfer of learning. For example, the benefits of an in situ simulation are that it helped detect pitfalls in the actual work environment and helps in development of the working environment. The contextual aspect of meaningful learning can be supported by planning and designing real-life cases and environments. In addition to full-scale simulations, computer-based simulations, videos, Internet links, and worked examples can be used to support learning (Alinier 2011; Dolmans et al. 2005; Jonassen 1995; Keskitalo 2011, 2012; Löfström and Nevgi 2007; Merriënboer and Sweller 2010; Ruokamo and Pohjolainen 2000).

Goal-Oriented

Goals direct our thoughts, behavior, and strategies; thus, setting clear goals should be encouraged (Dieckmann 2009; Schuzt and DeCuir 2002). This entails adducing the general learning objectives, as well as encouraging learners to set their own learning goals (Dolmans et al. 2005; Jonassen 1995; Keskitalo 2012; Keskitalo et al. 2011, 2014; Schuzt and DeCuir 2002). For this task to be complete, the facilitator is also responsible for diagnosing learners' needs.

Self-Directed

Simulation-based learning is about educating adult learners who are self-directed and intrinsically motivated (Fanning and Gaba 2007). This means they set up individual learning goals and follow up on those goals during the learning process (Brockett and Hiemstra 1991). The facilitator maintains these learners' activities by supporting, guiding, and giving feedback. In simulation-based learning environments, for example, video recordings, debriefings, learning

diaries, observational ratings, tests, etc., can be used to evaluate learning.

Individual

Learning is different for each individual (De Corte 1995); therefore, individual differences should be considered whenever possible (Alinier 2011; Zigmont et al. 2011a). Individualized learning was also recommended by the Carnegie Foundation for Teaching and Learning of Medicine (Irby et al. 2010). The facilitator's task is to take into account individual differences, diagnose individuals' development level, and provide individual guidance and feedback (McGaghie et al. 2010; Keskitalo et al. 2014; Ruokamo and Pohjolainen 2000). The learning environment, tasks, and materials should also support individual learning styles, and the environment can be changed to meet various needs. The facilitator familiarizes himself or herself with the students and gives individual feedback and support.

Phases of the Pedagogical Model

The pedagogical model provides an example of *how* learning with simulations in healthcare can be scripted. The model includes six distinct phases: Pre-activities, Introduction, Simulator and Scenario Briefing, Scenarios, Debriefing, and Post-activities. The characteristics of meaningful simulation-based learning can be realized through these phases. Next, these phases are presented in more detail.

Pre-activities

There are specific tasks for facilitators and learners during the pre-activities phase of simulation-based learning, that is, before the actual face-to-face interaction. Learners' responsibility in this phase is to get acquainted with the theoretical content knowledge. This can be done through pre-assignments, trigger videos, readings, lectures, etc. Learning with simulation demands much work from the facilitators before it even starts. The facilitator's preparatory tasks include considering the target group and their learning needs, designing the learning objectives, and

preparing the learning material, assignments, case scenarios, and environment, among other things. According to Alinier (2011), more realistic scenarios require more time to prepare. The more experienced the learners are, the more realistic the scenario should be.

Introduction: Activating Previous Knowledge and Setting the Ground

The actual face-to-face phase starts with an introduction, the most important goal of which is to prepare the learners for the learning process and set a safe scene for learning (Arthur et al. 2013; Clapper 2010; Rudolph et al. 2008). In the beginning, participants get to know each other, and a facilitator explains the course topic and its objectives (Zigmont et al. 2011a). In addition, activating learners' previous knowledge and experiences, as well as discussion of important or otherwise difficult concepts, is important for the formation of new knowledge (Dolmans et al. 2005; Zigmont et al. 2011a). In conclusion, the purpose of the second phase is to set the ground rules and establish a safe and supportive environment for learning.

Simulator and Scenario Briefing: Familiarization

During this phase, learners get to know the physical environment and the case scenario on a general level. In addition, the simulation-based learning environment with all the technology the participants will be required to use is introduced. This phase should also involve hands-on exercises in order for learners to get acquainted with the simulator and other technological devices (Dieckmann 2009). By the end of this phase, the learners need to feel comfortable with the learning environment so they can practice effectively in the next phase.

Scenarios: Guiding and Participating

The scenarios phase is the heart of the simulation-based education. Without the case scenario, there is no learning with a simulation. During this phase, learners participate actively in the simulation and treat a patient, while the facilitator stays in the background and closely monitors the

learners' actions. In this phase, the crucial question is whether to interrupt the exercise if it is going in the wrong direction. Some suggest that the simulation can be interrupted so that learners may still achieve their learning goals (Dieckmann 2009), but others have stated that interrupting the simulation spoils the simulation realism (Fanning and Gaba 2007; Franklin et al. 2013). Based on the study by Garrett et al. (2011), learners prefer seeing the consequences of their actions for the patient's condition. This may also enhance student learning, as shown by Goldberg et al. (2015).

Debriefing: Facilitating and Reflecting

Debriefing is commonly regarded as the most important phase of learning with simulation (Fanning and Gaba 2007; Motola et al. 2013; Wang 2011) because that is when learners can review and reflect on their learning and identify any knowledge gaps. During the debriefing process, participants are responsible for reviewing and reflecting on the entire learning process, as well as identifying their knowledge gaps and forming new learning objectives, whereas the facilitator's role is to be a "cognitive detective" (Rudolph et al. 2008, p. 1011). As Pasquale (2013) stated, reflection is thinking about thinking, but in learning with simulation, it is also thinking about doing. In this phase, the facilitator's role is to encourage students to analyze the entire experience in order to enhance their learning and future practice by asking open-ended questions (Fanning and Gaba 2007; Keskitalo et al. 2014; Rudolph et al. 2007) and actively listening (Ahmed et al. 2012; Zigmont et al. 2011b). Specific individualized feedback and emotional support are also regarded as important by learners (Keskitalo 2011; Keskitalo et al. 2014; Walton et al. 2011) and facilitators (Ahmed et al. 2012).

Previous studies have proposed different models for conducting the debriefing phase (Dreifuerst 2012; Dufrene and Young 2014; Fanning and Gaba 2007; Nyström et al. 2016; Rudolph et al. 2007; Steinwachs 1992; Zigmont et al. 2011b), although there is currently no clear evidence that one method is better than another (Dufrene and Young 2014). Steinwachs' (1992)

model is a very commonly used approach (see Ahmed et al. 2012; Gardner 2013; Konia and Yao 2013; Nyström et al. 2016; Rudolph et al. 2008; Zigmont et al. 2011b). It includes three phases: the description phase (what happened, first impressions, and feelings), the analysis phase (exploration of the reasons for learners' decisions and actions), and the application phase (the take-home message and future learning goals). However, research on debriefing from the sociomaterial perspective revealed that this type of scripted learning discussion does not support learners' initiatives (Fenwick and Dahlgren 2015) and it is a teacher-centered approach to learning.

Post-activities

The final phase of learning with simulation is the post-activities phase that is often under-examined in research, although this phase is important for continuous development of learners' expertise and the development of simulation-based education (Boese et al. 2013). For learners, this phase includes application of knowledge and skills in a new scenario or in real life (see Kolb 1984; Merrill 2002). For the facilitator, post-activities mean evaluating learners' learning processes and developing the education further. Wang (2011) proposed two frameworks that can be used to that end, Kirkpatrick's (1998) and Kneebone's (2005). However, the characteristics of meaningful simulation-based learning can be used to evaluate simulation-based education. For example, the facilitator and learners may evaluate how well the individual aspect of learning was realized. If this aspect is not realized well, they may think of ways to realize it better in the future.

Conclusions

Previous studies have shown that simulation-based learning is beneficial, but future studies should concentrate on the underlying teaching and learning processes that have led to these successful outcomes (Garden et al. 2015). According to Cook and others (Cook et al. 2011), we do not know enough about when, how, and to what the simulation-based learning environment should be

applied. In the other words, it is known that learning with simulation works but how exactly remains unknown. This knowledge would help us to optimize the use of simulations in healthcare education.

Cross-References

- [Digital Simulations in Healthcare Education](#)
- [Games, Simulations, Immersive Environments, and Emerging Technologies](#)

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Learning with Technologies

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Lifelong Learning for Working People

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The idea and practices of lifelong learning are now commonplace across much of the world, largely as a result of policy responses to accelerating economic change (Field 2006; Tuijnman and Boström 2002; Zapp and Dahmen 2017). The challenges to which lifelong learning is said to propose a solution, though, are multiple and complex. Across the globe, new technologies from digitization to robotics have come together with globalization off the economy and the consequent reconfiguration of work to transform the labor market for new entrants while placing new demands on older workers to adapt to changing career prospects. In many countries, particularly the established economies of North America, Asia, Europe, and Australasia, these trends are further impacted by a general shift away from manufacturing toward service employment, as well as by important social changes, including population aging and growing diversity arising from migration. At the same time changing social values have led to new expectations around the transition from education to work, as well as greater equality of access to working life and its rewards, along with wider interest in the quality of working life and its relationship to the rest of our lives.

Whether it is realistic to see education and training as the answer to these challenges is debateable. The entry explores the ways in which these tendencies have affected the demand for and supply of skilled labor, with considerable implications for governments, employers, and

workers. The idea of lifelong learning can be understood as a response to these conditions, involving as it does the belief that workers of all ages and across sectors will be required to continue updating their skills and qualifications throughout their working lives. The entry will review policy responses by governments and international government bodies such as the OECD; it will also attempt to summarize the main trends in employer responses, though these are inevitably diverse and uneven. It will also examine the available evidence on trends in worker participation in continuing education and training. Finally, it will review the ways in which information technology is being adopted as a solution to the challenges of continuous workforce development and cautiously assess the impact of these developments, including recent initiatives in open education.

The Inexorable Rise of Lifelong Learning

The OECD recently commented that: “Skills have become the global currency of the 21st century” (OECD 2012, 3). Such language is familiar, and the case for investing in skills is widely accepted – so much so that there might be a risk of taking it for granted. In recent years, governments have responded to the challenges of the global knowledge economy by paying increasing attention to skills and education, not only among young people still in school but also among the existing workforce. While one possible response to population aging in the West is to attract skilled migrants, this is often politically controversial, and anyway migrants also grow older over time. And one country’s immigration is another country’s emigration, leading to a loss of skilled workers with subsequent negative effects on productivity and competitiveness (Docquier et al. 2014). So for many governments, as well as for many enterprises, increasing the adaptability, productivity, and employability of workers and improving their capacity for lifelong learning present a pressing challenge.

The European Commission, one of a number of international and national government bodies that

has recently embraced the idea of lifelong learning, defines it as “all learning activity undertaken throughout life, with the aim of improving knowledge, skills and competences within a personal, civic, social and/or employment-related perspective” (Commission of the European Communities 2001, 9). What was significant here was not simply the idea of developing policies for learning at all stages of the life course but also the idea that learning took place in all spheres of life and not just in formal educational settings. Like most other government bodies, the Commission emphasized the breadth of the term, which they understand as encompassing “the full range of formal, non-formal and informal learning activity” (Commission of the European Communities 2001, 9).

The breadth of this definition poses challenges to policy-makers, as it potentially addresses any form of learning – however trivial, wherever undertaken, and whether the learner is conscious of it or not. But it was clearly intended to shift attention away from an input model which focused on planned instruction in formal settings, toward an output model which focused on the learner and his or her development. It was therefore consistent with the slightly earlier shift in those concerned with promoting learning at work, who increasingly described themselves as human resource developers or coaches and less and less as trainers. And more broadly, the language of skills and training is itself changing as part of this preoccupation with learning throughout and across the life course. Simply to take one particularly striking example, the organization founded in 1943 the American Society of Training Directors, which changed its title in 1964 to the American Society for Training and Development, renamed – and rebranded – itself in 2014 as the Association for Talent Development, or ATD (Torraco 2016).

These developments have expanded the contexts and concepts of work-related learning beyond the relatively narrow confines of the classroom or training center. Unsurprisingly, popular understandings of training tend to be far more narrow and specific than the broad definitions that are used by researchers and policy-makers, and it follows that training levels go underreported in many

surveys (Campanelli and Channell 1994). More recent evidence from the UK Employer Skills Survey suggests that many managers do not recognize coaching or mentoring as forms of training, but are likely to understand training as involving a relatively simple transfer and acquisition of knowledge and skills between expert and novice (Winterbotham et al. 2011, 11–14). Rather than an “acquisition” mode of learning, recent theories of learning have tended to understand learning in terms of “participation,” “construction,” or “co-construction” (Sfard 1998; Engeström 2001; Illeris 2018).

The notion of skill at first appears relatively straightforward, at least by comparison with the idea of training. But again it has connotations that can be loaded down with cultural baggage, and these too have evolved and changed as a result of new perspectives. In general, the idea of skills has acquired a strongly positive gloss, and it has sometimes displaced older terms like adult training or education. For example, the Organisation for Economic Co-operation and Development has branded its international study of workers’ basic competences as the “adult skills survey” (OECD 2013). In Britain, the word was for long associated with status hierarchies inside the labor force; a “skilled worker” (or, often, a “skilled man”) was someone who had completed a particular type of apprenticeship and whose status and autonomy was often fiercely protected by trade unions. More recently, the term has been enlarged in response to underlying changes in the economy, which have resulted in the use of the term to encompass attributes such as communication, teamwork, problem-solving, creativity, and other so-called generic skills or soft skills.

In practice, though, much workforce training is not really concerned with learning new skills – at least, not in the sense in which most people use the word. Quite a high volume of training is undertaken in order to comply with legislative requirements or regulatory frameworks, which demand that people train to a specified standard regardless of whether they already have this knowledge or not. In Britain, for example, 71% of employers reported that they had provided health and safety training in 2011 (Davies et al. 2012, 113), almost

all of which was designed to underpin compliance with legislation.

Widespread adoption of the language and idea of lifelong learning has involved a new verbal emphasis. This has affected perceptions of those involved professionally in the field, with many people now referring more to supporting learning rather than providing training and teaching. Illeris dates the origins of this change back to the 1970s, when influential theorists such as Argyris and Schön helped to refocus attention on acquisition rather than instruction; by around 1990, he suggests that the language of learning increasingly took on a social dimension, evident not only in concepts of situated learning or activity theory but also in more popular notions of the learning organization, learning city, or learning region (Illeris 2018). Greatly influenced by the seminal and popularly written work of Jean Lave and Etienne Wenger on situated learning, constructivist theories emphasize the ways in which workers produce and share their skills and knowledge through participation in the workplace (Lave and Wenger 2001). In this model, rather than trainers and trainees, learning occurs when a novice participant is accompanied and guided by more experienced workers from peripheral to full participation.

Yet although learning is increasingly seen understood by many practitioners and researchers as an intrinsically social practice, policy perspectives often focus on the role of individuals. I have argued elsewhere that the discursive shift toward lifelong learning is associated with a wider rebalancing of responsibilities for learning, with a reduced role for the state and increases in the responsibility of individuals and employers to invest in and coordinate upskilling and talent development (Field 2006).

These definitional and terminological issues help us understand why it can sometimes be challenging to agree on how skills and training should be measured. At enterprise level, Kirkpatrick’s model of training evaluation has dominated the field since its first publication in the 1960s (Kirkpatrick 1967). This model proposed four “levels” of criteria for evaluating training: reactions, or how people feel about the training they have received; learning, or what they know as a

result of the training; behavior, or what they can now do; and results, understood as the influence that the new skills and knowledge have on the organization's performance. While this model has been widely criticized in the academic literature as oversimplifying training, and presenting the outcomes as a linear sequence organized in an unproblematic hierarchy, its clarity and applicability continue to appeal to professionals in the field (Yardley and Dornan 2012). Surveys of current practice tend to confirm the view that few organizations have moved toward more creative ways of evaluating and measuring training. In countries such as the UK, for example, the most frequently used tools are post-course evaluations (commonly known as "happy sheets"), and individual testimonies, followed by attempts to measure outcomes, and finally by assessments of the impact on key business objectives (CIPD 2011, 5). Similarly, most US training managers use only the low-effort levels of evaluation, such as measuring participant reactions and assessing their learning, with relatively few attempting to estimate the results in organizational terms or calculate the return on investment (ASTD 2010, 21).

This focus on simple evaluation tools is a rational response to the difficulties of estimating the organizational return on investment from training. The first challenge is to distinguish the effects of training from all the other factors in the workplace that might affect productivity. Very few studies have tried to separate out the impact of training from the effects of other strategic interventions, such as team membership changes, appraisal, profit sharing, or worker participation in decisions (for an exception, see Akhtar et al. 2008). The second is to discriminate between the effects of training on the worker and the influence of the worker's characteristics on skills acquisition; economists believe, for example, that employer selection decisions are biased in favor of the most capable workers, so that employers sometimes overestimate the results of training activities (Vignoles et al. 2004). Third, at company level, there is some empirical support for the intuitive belief that low-performance enterprises are less likely to train than high-performance enterprises (Dearden et al. 2006; Zwick 2006). Finally, there

is the question of time scale: in many cases, a considerable time period is needed to monitor the effects of training, yet company goals are often measured over the short term; even if managers are willing to take the long view, the prospects of other factors intervening are increased.

Economics, particularly in the form of human capital theory, has made a particular contribution to the measurement debate. Essentially, this theory states that skills and knowledge represent a form of capital, part of which is the result of deliberate investment. Initially the idea was developed by Theodore Schultz as a way of exploring the economic value of education, particularly in relation to economic growth (Schultz 1961). Subsequently the theory was developed by Gary Becker, who extended the analysis to include continuing training as well as other investments in skills, as well as developing a sophisticated cost-benefit analysis as a way of explaining educational decisions. Becker distinguished, for example, between general training, which he claimed was mainly of benefit to the worker as it raised their future wages by improving their attractiveness to other employers, and firm-specific training, which he saw as more likely to benefit the employer, by raising productivity without raising wages (Becker 1993, 31–51). For Becker, this distinction meant that employers would pay for specific training, but normally general training would be paid for by the worker. He also argued that employers would invest more in those workers where they could expect the greatest return, one side effect of which was lower investment in women workers who typically spent less time in the labor force than men (Becker 1993, 88).

Human capital theory has been widely criticized for what some see as its excessive individualism and its reliance on rational choice models of decision-making (Field 2003, 21–22; Tan 2014). By treating skill as an attribute of the individual worker and explaining all decisions as the result of rational calculations of individual rates of return, it is argued that human capital theory is deeply flawed conceptually and unable to deal with the socially embedded nature of decision-making. The theory has also been attacked

for its use of oversimplified tools of measurement, such as years of schooling or the gaining of formal qualifications, which are unrelated to actual skills and abilities. Finally, it tends to present a direct linear model of investment and return, yet empirically much research on returns to education have suggested that the relationship may be multilinear and iterative (these concerns are rehearsed in Field et al. (2000, 249–251). Nevertheless, the theory certainly has some explanatory power and has been widely supplemented by forms of cost-benefit analysis to inform decisions about the funding of training and development activities.

Securing Knowledge and Skills Development

Skills and their development command almost universal support. Policy-makers proclaim that upskilling will lead to greater competitiveness, inclusion, and cohesion, while employers and trade unions alike proclaim their support for training and development. In fact, it is virtually impossible to find anyone who opposes upskilling. In part, this arises from simple demographics. The US Census Bureau expects more than 20% of residents by 2030 to be aged 65 and over, compared with 13% in 2010 and 9.8% back in 1970 (US Census Bureau 2014). Other advanced nations, particularly Japan and South Korea, anticipate much more dramatic rises in the proportion of over 65s (Bengtsson and Scott 2013). Conversely, the share of those of traditional working age in the population is falling, and governments, employers, and individuals increasingly accept that working life will, in many cases, be longer than most people previously expected. The adaptability and employability of this aging workforce, and therefore the productivity and competitiveness of enterprises and nations, depends in large part on the extent to which it can continue to develop and apply new skills and abilities.

Governments, individuals, and employers have an interest in developing strategies for upskilling the workforce and developing potential. Yet despite the policy consensus in favor of upskilling, and widespread evidence that it has

both private and social benefits, there are controversies over the best ways of promoting continuing training. Particularly contested areas include the funding of training, and in particular, the question of who should pay for what? To what extent should the state intervene, whether as direct provider of learning and development or as an enabler and incentivizer? Moreover, as well as the financing of skill formation, Busemeyer and Trampusch identify three other “neuralgic points” of conflict: the tension between enterprise autonomy and state involvement (who controls what), the balance between school and firm in initial vocational education and training, and the relationship between the VET system and the wider educational system (Busemeyer and Trampusch 2012b, 16). In addition, when it comes to continuing skills development for the adult workforce, there is the question of what involvement public education bodies such as universities and colleges should have and on what basis.

Moreover, much policy focus has concentrated, perhaps understandably, on areas of identifiable growth. In occupational terms, this has often led policy-makers to present summaries of labor market trends that show an increase in high-skill employment and project a continued decline of low-skilled jobs. However, as the OECD has noted, while there is indeed growth in some high-skill occupations, such as managers and scientists, the loss of traditional male unskilled jobs has been largely balanced by a growth of low-paid service jobs, which happen often to be performed by women and migrant workers; it is the middle-skill jobs that tend to experience relative declines, whether in services or in manufacturing, partly because these occupations can be transformed through computerization or even automation (OECD 2010, 24–25).

From a policy perspective, the pace of change and the degree of uncertainty in the labor market imply a focus on providing workers with robust skills and the capacity to develop new competences. This requires strong basic skills (literacy, numeracy, and information technology) through initial education or through compensatory measures for those who did not develop these basic skills earlier in life. Increasingly, governments are also seeking ways of

developing what are sometimes called generic or key skills or transversal competences, such as problem-solving, teamworking, communications, and, perhaps above all, “learning to learn” (Commission of the European Communities 2010, 10). In developing its policies for skills and employment, the European Commission continues to call for “comprehensive lifelong learning” as a way of achieving the balance of flexible and secure employment that it describes as “flexicurity” (Commission of the European Communities 2010, 5–6).

There is also an emerging debate over the balance between supply and demand. Particularly in Britain, it has been argued that public policy focuses almost exclusively on the supply of skill, largely ignoring other factors involved in determining productivity, such as investment strategies and work organization (Keep et al. 2006). In some countries, though, policy attention has recently widened to encompass the utilization of skills as well as their formation. This development is usually dated back to a 2001 report, in which the OECD argued that it was not enough simply to invest in improved skills; if new skills were to contribute to improved performance, it proposed that work practices must also change. This was not, the OECD stated, simply a matter of introducing new techniques and tools; it also meant “a reorganization of work,” with particular attention to such factors as employee involvement, flexible working, and flatter hierarchies that favored high-performance working and technological innovation (OECD 2001, 15–16). OECD has described these features as characteristics of the “learning organization,” accompanied by human resource practices that are aligned with the goal of continuous learning and smooth internal communications (OECD 2010, 73–74).

So far, the policy implications of a focus on skills utilization are not entirely clear. Nevertheless, strategies that seek to make the best use of existing skills, as well as developing new ones, have considerable potential if they can be operationalized in concrete ways. They are likely to be particularly important for enterprises that employ significant numbers of such groups as older workers, who are likely to remain active in the labor market where their existing knowledge

and competences are recognized (Canning 2011; OECD 2012, 64–72). While there are some individual examples of improvement in skills utilization at enterprise level, sometimes involving support from trade unions as well as managers, this remains a work in progress (OECD 2017).

Developing Skills in Practice

Investing in skills can take a variety of forms. Particularly with the advent of interest in lifelong learning, human resource managers have started to explore a broad range of ways of developing skills. In part, this is also a response to the changing nature of work, as well as to the increasing potential of new technologies as ways of communicating information and ideas. A number of studies suggest that while face-to-face delivery remains the norm, it is increasingly being challenged by newer forms of training (CEDEFOP 2010, 65). These include blended learning, coaching, and mentoring, all of which appear to be particularly prominent in the UK but are being widely adopted across the European Union (Observatoire CEGOS 2012, 3). More radical forms of innovative learning, such as job rotation and learning circles, are used relatively rarely; however, job rotation is an important additional form of training in some countries, particularly Sweden and Austria, while learning circles are similarly important in Austria and Denmark (CEDEFOP 2010, 66). Finally, the adoption of digitized learning resources, and their often instant availability through mobile devices, is increasingly influencing approaches to supporting lifelong learning at work and in the community.

Estimates of the overall volume of skill development are plentiful, but often difficult to interpret. The 2010 European Continuing Vocational Training Survey found that participation rates ranged from a low of 11% of the workforce in Latvia to a high of 59% in the Czech Republic, with an average of 38% (up from 33% in 2005); the proportion of enterprises providing training ranged from 85% in Denmark down to 21% in Greece (CEDEFOP 2015, 66–69). Trend data suggest that adult participation in training is

rising. According to one global survey, the proportion of employers training and developing existing employees to fill open positions doubled between 2006 and 2016 from one in five to over half (Manpower 2017). Of course, these are overall figures. In practice, participation in training varies enormously across the workforce.

Training provision varies by sector, with the highest participation rates found in sectors involving person-to-person services. In the UK, for example, the Employer Skills Survey has shown that training levels are much higher than average in health, social care, and education, followed closely by public administration and financial services; it is notably below average in agriculture, manufacturing, transport, and communications (Davies et al. 2012, 110). European data also suggest that formalized arrangements for training are most common in the finance sector, followed by the gas, water, and electricity industries (CEDEFOP 2015).

Perhaps unsurprisingly, participation is higher in firms where collective bargaining covers training than in those where there are no joint agreements (CEDEFOP 2010, 55–57). Some governments actively involve trade unions in promoting levels of training and ensuring its relevance. In the UK, for example, the government sought to promote investment in training by encouraging the appointment from 2000 of workplace union learning representatives (ULR); by 2009, over 10,000 union members had served for at least a period as a ULR, most of whom had never held a union office previously (Saundry et al. 2010, 12). The UK Government also supports trade union provision of education and training through its Union Learning Fund. Managers reported that in some cases, ULRs have also helped develop new courses, particularly in basic skills areas such as literacy, computing, and numeracy (Saundry et al. 2010).

Participation also varies by worker characteristics. Age is a major factor, with participation falling rapidly over the life course (Boateng 2009, 3). According to OECD data, older people also receive the lowest number of hours of continuing training (OECD 2011, 367). In aging societies, the retention and productive employment of older workers is a key issue for governments and

for many enterprises, as well as for older workers themselves. Encouraging greater upskilling though lifelong learning is a popular policy response, though its importance and form will vary according to the existing level of older workers' skills. In countries like the USA, where older workers perform well in skills assessments and also appear to use these skills as much as younger workers, employability rates for older workers tend to be relatively high. Even in ICT usage, survey data suggest relatively low age differentials across the US workforce (OECD 2018, 77–78).

Immigrant workers experience lower levels of training than the native born (Rosenblatt and Bilger 2011, 67). Occupational status is another factor, with participation rates rising among white collar workers and peaking among managers and professionals (Boateng 2009, 4; Rosenblatt and Bilger 2011, 68). And it varies by prior education, with particularly low participation rates in most countries among workers with no formal qualifications (Boateng 2009, 5; OECD 2011, 377). Seen from the perspective of human capital theory, the most precarious and least skilled appear to represent a poor investment. There is some empirical support for this generalization, in the form of survey evidence on the priorities of human resource and training managers in enterprises (Observatoire CEGOS 2012, 4). In general, these patterns can be found across most countries, though the inequalities are greater in some cases than others.

Gender is also a factor that affects participation, though not necessarily in a straightforward manner. Some evidence points to an under-representation of women. For example, in 18 of the 25 countries covered by the OECD, men received more hours of training than women (OECD 2011, 368). However, overall figures for the UK suggest that training provision is broadly in line with the share of women in the workforce, while female participation is slightly above that of men (Canduela et al. 2012, 47; Department for Business, Innovation and Skills 2008, 29). The same has been found for Germany, where roughly the same proportions of men and women participate in vocational training (43% against 42%); among

part-time workers in Germany, women were more likely to undergo training than men (Rosenblatt and Bilger 2011, 65–66). These patterns can be extremely difficult to interpret and evaluate, partly because of the persistence of gendered labor markets, arising from the tendency of some occupations to remain predominantly female while others remain predominantly male. There is also some evidence that some women, particularly those with caring responsibilities, tend to make different occupational choices from men, though whether this is for positive or for negative reasons remains contentious (Hakim 1996). One analysis of data from the European Social Survey, which controlled for such other factors as worker and occupational characteristics, found that all other things being equal, male workers in any given category were more likely to participate in training than their female equivalents (Dieckhoff and Steiber 2011). For some commentators, this is explicable in terms of human capital theory: employers are likely to invest less in women workers because they are less prone to stay with the firm, and therefore the return on investment will be lower; and women workers are likely to underinvest in training if they see themselves as secondary earners (Hakim 1996, 69, 121). In so far as these factors cease to characterize women workers, then the human capital argument implies that women workers will receive similar training investment to their male counterparts.

Such equity issues have a wider importance, as a number of studies show that for people of working age, access to education is largely decided or denied by their occupational position. Work-related learning accounts for much participation in adult education more generally (Boateng 2009, 3). More broadly, much of the variation in participation in learning more generally appears to be explained by transitions in the workplace (Biesta et al. 2011, 38–40). As we have seen, moreover, participating in training has a number of positive outcomes for individuals and organizations, as well as for regions and nations. In adopting lifelong learning policies from the late 1990s, a number of countries insisted that their policies would promote “lifelong learning for all,” in the belief that the new economy required a step change in

skill levels across the board and not only among a small number of key workers (Field 2006; OECD 2012). Relatively few countries have succeeded in achieving this balanced approach to skills, though in general, the open Nordic economies tend to be characterized by high overall participation and low levels of inequality. Drawing on survey data, Dieckhoff and Steiber found that although inequalities were similar in all the 25 countries studied, they appeared to be less pronounced in the Nordic nations (Dieckhoff and Steiber 2011, 151).

The question of how training is financed is both complex and vexed. There is considerable controversy over the level of investment in skills, as well as in the distribution of investment between government, workers, and employers; furthermore, levels of government support vary considerably across countries. In general, large firms tend to spend more per worker on training than smaller firms (Davies et al. 2012, 124; CEDEFOP 2015, 178–179). The average spend is also higher in financial and business services than in other sectors (CEDEFOP 2015; Davies et al. 2012, 129). Analysis of the European CVT Survey suggests an average spending by enterprises across the EU on training of 1.6% of total labor costs, ranging from a high of 2.5% in France to a low of 0.7% in Greece (CEDEFOP 2015). Spending in the United States was somewhat higher, averaging around 2.14% of payroll (ASTD 2010, 9). The contribution coming from government varies both in level and type; in Europe, types of government support at national level range from tax incentives and direct subsidies to grants to firms or individuals, with subsidies also available from the European Commission to support some types of training program within the member states.

Professionalization of training has developed unevenly in recent years. Across Europe, some 15% of enterprises have a training center, 32% have a dedicated training budget, and 42% have a named individual with overall responsibility for training. In all these cases, larger firms were more likely to have dedicated resources, and smaller firms were less likely (CEDEFOP 2010, 38–40). As for training supply, much takes place within

the private sector, which is large and fragmented, with a small number of very large providers, often providing training as one of several business services or as an addition to their main product (as in IT supply), and a very large number of small providers, including a sizeable number of sole traders who may provide training on an intermittent or part-time basis. In many countries, this disparate private sector has grown rapidly. A study conducted just before the recession in the UK noted that the number of training providers registered for value-added tax doubled between 2000 and 2008 (Simpson 2009, 10).

A number of commentators have singled out the Northern European nations as particularly successful, often attributing their effectiveness at skills formation to the arrangement of institutions that are sometimes referred to as “coordinated market economies” (Green et al. 2006). Of course, such arrangements are themselves dynamic and must adapt to changing circumstances. They are currently in a significant process of adjustment as a result not only of globalized competitive pressures and the shift away from manufacturing and primary industry but also as a result of Europeanization and changing political complexion of the governments (and electorates) involved. While these change factors are commonly acknowledged in the literature (see the essays in Busemeyer and Trampusch 2012a), it is less often recognized that these collective skill arrangements appear to be much stronger in strengthening initial vocational training than they are in promoting continuing skills development.

Trends and Prospects

Skills development is widely embraced as a way of securing future success in an uncertain economic environment. In many countries, investment in adult training and development appears to be increasing in response to widely shared challenges and opportunities. Yet although there is a strong general consensus on the value of skills, and the need to promote learning and development throughout working life, there is less

agreement on the priorities and methods to be adopted. Partly this is because there are real differences of interest at stake, in a context where different parts of any organization will have different interests and where information about the outcomes of training is often incomplete and unevenly shared. It is still common for many managers to view training as a cost, rather than as an investment; and it is also common for governments, particularly in the more liberal economies like Britain and the USA, to separate training programs for vulnerable groups (such as the unemployed) from policies for skills training in industry, which tend to view training as primarily a private concern. This is, then, a field characterized by continuing tensions and uncertainties.

Some of these arise from conflicts between current economic patterns and interests on the one hand and those that we may view as desirable to achieve sustainable growth. If policies focus on skills for high-performance organizations, which may be in the long-term public interest, then they will likely neglect those organizations that specialize in low-cost and low-quality goods and services. Yet in the actually existing economy, low-skill employment may be an important driver of growth for certain regions or nations, even if its long-term fortunes are highly vulnerable to competition from other low-cost regions. Moreover, I have already noted that much recent research into skills development tends to emphasize the importance of knowledge creation within work teams, which requires a very different approach to strategy and policy from traditional training responses (Felstead et al. 2009, 203–48). Research into informal learning in the workplace has demonstrated the significance of relationships of reciprocity and trust, which enable the sharing of ideas, techniques, and solutions to problems. Strategies and policies that foster such conditions are likely to prove extremely challenging for many managers, and also for many trainers, who will see them as involving decisions and choices that are outside their traditional expertise. Despite improvements in recent years, moreover, human resource development still has relatively low status within many organizations. The dominant management cliché, which speaks of people as

“our most important asset,” risks reinforcing a culture of cynicism unless it is supported by real substance.

A further source of tension arises from the growth and proliferation of training suppliers. The growing economic importance of learning in a global knowledge economy creates new economic opportunities for skills developers and trainers. We can see this in the rapidly expanding number of private providers in the UK (Simpson 2009). The “third sector” of voluntary and charitable organizations is also extremely active in many countries in providing training. In this ever more complex and crowded market place, quality assurance becomes a crucial issue. Among other “kitemarks,” the continuing development of specifications through the International Organization for Standardization (ISO) is a particularly important example of a wider development. Most recently, the ISO has approved basic requirements for providers of learning services in nonformal education and training, ISO 29990:2010. Its underlying aim is to enhance transparency and allow comparison on a worldwide basis of learning services. However, this too is a crowded field. Within the EU, member states and the European Commission have been working to establish a European Quality Assurance Reference Framework (EQAVET) to promote and monitor continuous improvement of national systems of vocational education and training (VET). Whether such schemes will develop any traction in such a disparate and growing area, which at present is largely unregulated outside certain specialist areas, remains at present an open question.

Skills and learning are also being transformed by the very processes of change and adaptability that they are often intended to address. This is visibly the case with new technologies, where digitization in particular has started to transform the availability and portability of learning resources, as well as widening the scope and reach of older training methods such as simulations and game-based learning. Massive open online courses are one example; an initial scoping report for the OECD suggested that they were “particularly well-suited to corporate learning and development,” partly because of their accessibility and low cost, as well as the possibilities for peer

interaction and credentialization that the technology affords; they were less good, though, at engaging less motivate learners, and their large scale made them unsuitable for personalized development (OECD 2016). Newer and more flexible forms of open education, from the adoption of open educational resources to gamification, are still in their early stages; whether they can overcome some of the limitations of MOOCs is still unclear, and at the time of writing, their use is mainly in the form of blended learning, complementing more established face-to-face forms of training and development.

Skills development for the adult workforce is one of the main levers for survival and success in a highly competitive global market place. By the same token, it must play a central role in expanding workforce participation and ensuring that all are able to make the most of their potential. It is therefore a topic of interest to policy-makers and researchers, as well as to those who lead enterprises and manage their workforce. As we have seen, there is also a substantial body of evidence that demonstrates the impact of training and skills development for individuals, which means that the subject is therefore of wider social interest to the public and the media. Sometimes, skills and training can be presented as “magic bullets” which will crack a previously unsolved problem, from racism in the police to disasters on oil rigs. Yet there is often a sense that skills and training are “unsexy” subjects that only hit the headlines when things go wrong, or when they impinge upon an issue of wider concern, such as youth unemployment. The vested interests in the current focus on initial training and education for the young are powerful forces; if we are to witness a shift toward upskilling the whole workforce at every stage of working life, as recent policy trends imply, then the degree of culture change required will be very considerable indeed.

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Literacy and Technology

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Synonyms

[Cognitive flexibility](#); [Cognitive load theory](#); [Con- structively responsive reading](#); [Knowledge gap theory](#); [Multiliteracies](#); [Multiple documents liter- acy](#); [New literacy studies](#)

Introduction

Literacy and technology is a contested and con- troversial field for a number of disparate reasons. There are a number of different definitions of literacy and these are often seen as perspectives

from specific domains, such as cognitive psychol- ogy or sociology or anthropology. Views in rela- tion to technology are no less contested and are often polarized in terms of technological deter- minism and technological evangelism. Various strands of contention must be understood to clearly appreciate the issues surrounding literacy and technology through the widest lens.

A Short History of Literacy and Technology

Many recognize technology in relation to the rise of digital practices, but those in the realm of media ecology would broaden the field significantly and point to technology as having a much longer his- tory, enabling those making claims for it – espe- cially in relation to literacy – to stand further back and assess its impact over millennia, rather than decades or centuries (McLuhan 1964). Three scholars who have made wide-ranging claims for the importance of the technology of the written word, and its impact on literacy and literacy’s impact on the individual and society, are Eric Havelock, Jack Goody, and Walter Ong. Their research attests that the first use for literacy can be seen in the form of accounting (seen c. 3500 BC): economic transactions recorded in cunei- form, beginning with pictographic symbols, nec- essary for an increasingly urban civilization that needed more formal forms of record keeping (Ong 1982: 85). As writing developed, as can be seen in later Sumerian and Akkadian writing, mastery became increasingly difficult and reserved for a few elites. It was with the rise of alphabetic writ- ing, perhaps firstly seen with Ugaritic and then perfected in the Greek alphabet, that writing was streamlined to enable efficient reading and writ- ing, thus expanding its uses exponentially.

One of the claims that scholars such as Have- lock et al., and more recently Marynne Wolf (2008) and Susan Greenfield (2014), assert is that literacy enables deeper thought. Ong writes “To live and to understand fully, we need not only proximity but also distance. This writing provides for consciousness as nothing else does” (1982: 81). Eric Havelock (1973) looks back to Ancient

Greece to look at the connection between literacy and thought. With the intellectual achievement that was the Greek alphabet, it might be wondered why there was no sudden democratization of literacy. But like today, it can be seen that technology moved slowly where education was concerned. Ancient Greece was still very much an oral culture, but such cultures need ways of transmitting their codes and practices, their history, and accomplishments. The poetic tradition was the means by which these significant aspects of the civilization were being transferred from generation to generation. However, for this to be the case, then extensive powers of memorization had to be utilized and memorizing such large amounts of material affected the psychological and mental processes. For the Greeks to learn their history and to pass on what their culture held dear, was to identify with the emotional and psychological state of those whose lives they were passing on; that, with the further aids of repetition, rhythm, rhyme, and other poetic devices, was the only way to ensure that such vast swathes of knowledge could be remembered. Yet Havelock believed that it was this oral culture that was a chief obstacle to rationalism and reasoned, objective analysis. He notes that this is why Plato saw the great poets as the enemy of the people “and it is easy to see why he considered this enemy so formidable; he asks of men that instead they should examine this experience and rearrange it, that they should think about what they say, instead of just saying it. And they should separate themselves from it instead of identifying with it; they themselves should become the “subject” who stands apart from the “object” and reconsiders it and analyses it and evaluates it, instead of just “imitating” it” (1973: 29). For Plato, the examined life necessitated the use of literacy; the ability to analyze, categorize, rationalize, and evaluate.

Although there are many scholars today who defend these claims for literacy, these claims are contested by others who reject this “autonomous model of literacy” and see the rise in modern digital technologies as a way to focus on the participatory, collaborative, and distributed nature of what are often now called multiliteracies or new literacies.

New Literacy Studies

Brian Street is a significant opponent of the autonomous model which he also sees as a “technology of the mind.” Street (1984) was one of the earliest scholars involved in New Literacy Studies, a tradition focusing on literacy as a set of social practices rather than on the “schooled literacy” of reading and writing. Street believes that schooled literacy is value-laden and based on an assumed set of unquestioned beliefs (especially the autonomous model of literacy) that impose a Western capitalist model on those who submit to such practices. From this perspective, the autonomous model of literacy can be seen to marginalize certain cultures and peoples and come from a culture of power and domination. This perspective challenges categories and definitions used by those in authority, such as the United Nations, which can brand others as illiterate or as failing to meet a predetermined standard. Those holding to this autonomous model are also the ones who are seen to have the power to determine education policy and literacy programs, including pedagogy and text books. Instead Street proposes an “ideological model” of literacy, recognizing literacy’s social and cultural contexts and New Literacy Studies stresses a plurality of literacies, coined as multiliteracies by the New London Group. Building on the ideological model of literacy, multiliteracies values the various (often dismissed) practices involving print literacies, practices around multimodal texts, and practices around new digital and social media.

Literacies and Technology

James Paul Gee is another stalwart of the New Literacy School and its perspectives and he has written extensively on how, if literacy is seen as a set of social practices, then the use of digital technology is simply another social practice through which literacy can be manifested and understood (Gee 2015) Recognizing Ong’s early contribution to the field of digital technology and literacy, which he believed would introduce a new form of “secondary orality,” Gee develops this

analysis, though using the more positive term “retained orality.” Gee sees this form of hybrid spoken and written language in social media, as one aspect of the “new” in new literacies and an aspect of literacy practice that enables democratization and participation. Along with this aspect that digital technologies can contribute to new literacy practices, he shows that new modalities such as images (including moving images) and sounds meld with text to increase their richness and accessibility. As opposed to literacy practices that are often the domain of school, Gee points to what he calls “affinity spaces” (2015: 118–127) where these new literacies can encourage socially constructed knowledge and enable participants to engage not only in learning about information, but learning about themselves and building their own identities. In contrast to information encountered in school, Gee and others (see Knobel and Lankshear 2007) champion the distributed nature of online learning which challenges the domination of teacher and text book authority.

The rise of digital technologies has led to online affinity spaces which can enable a range of literacy practices. Technology has enabled such learning environments which emphasize collaboration and participation. This can be seen in the research of Rebecca Ward Black and her work in the field of Fanfiction (Ward Black 2008). She points to the “authentic” writing that can be seen on fanfiction sites, where fans of particular genres of media or specific shows, write fiction based on their following. She contrasts the liberty found in this medium with writing in school: “. . . texts produced in the classroom are artefacts of a print based culture and reflect the conventions of print as well as the constraints of academic genres and writing” (2008: 130). Taking New Literacy Studies as a framework for her analysis, she recognizes the benefits of such writing spaces where there is more room for experiment. One of her research studies looked at a Chinese girl and her fanfiction over a 2-year period. She noted the collaborative form of such work, where others on the site would comment and encourage so she could learn from the “community.” This feedback and her growth from learner to expert helped what Black described as the construction of the girl’s identity

as a successful fanfiction author. Black contrasts the active learning that these sites can offer with the “spaces of enclosure” found in schools. She also emphasizes the distributive nature of affinity sites, where there is a lack of authorised roles and imposed forms of knowledge (Ward Black 2008: 125–144).

Literacy practices in these spaces are heralded as collaborative and authentic. As well as contributors to such spaces being enabled to perfect their work through the use of digital tools such as spellcheckers, multimodal frames, and online authoring software, there are other passionate producers (a term coined by Muller (2009) combining the idea of consuming and producing) as can be seen from the above research, to scaffold and support the writer’s endeavor. This social emphasis points back to Street’s focus on literacy as a social practice and encourages practitioners to recognize their literacy events through such a lens. Gee states that “a classroom where learners did not choose to be there and where an authority figure grades everyone else is not an affinity space and cannot be one” (Gee 2015: 127). Technology has enabled literacy to thrive outside of such restrictions, where Gee notes (among other things) that there are many routes to status; people are not segregated by age, gender, race, class, or expertise; leadership is porous and roles are reciprocal.

Technology has also introduced the idea of gaming to literacy development. Gee recognizes this at the end of his book *Literacy and Education* (2015) and much of his research has focused on good games, i.e., games that have the ability to provide contexts for problem-solving, skills-based learning based on clear goals, instant feedback, collaboration, and enjoyment. Kurt Squire states that video games are “the heir to traditional print fiction” (Squire 2008: 106) arguing that the learning opportunities to be found there can be much richer and enable greater participation than the opportunities in schools which are still “shackled to literacies of print” (Squire 2008: 106). MMOs (massively multiplayer online games) are also seen to enhance learning (Plass et al. 2015), enabling participants across genders, socio-economic boundaries, age, and color to

collaborate in their endeavor. They are based around questioning, collaboration and play yet those involved in such social practices need a significant amount of learning and often require mature print literacy skills to understand and interpret the rules of the game.

Other literacy practices that have been enabled due to digital technologies include blogs, forums, trip and restaurant review sites, Tweets, and Facebook posts. These areas allow for many of the literacy activities already seen and are an integral aspect of most people's lives in the twenty-first century. There has been some research into mobile technology use in schools and where the focus has been on action learning, authentic learning, experiential learning, and social constructivism, the outcomes have shown that mobile technologies, such as iPads, can increase collaboration between teacher and student, increase effective feedback and increase face-to-face interaction between teacher and student (Falloon 2015; Genlott and Gronlund 2016). In some classrooms where research has been carried out, the focus has been on pupil autonomy, social constructivism, real world practices, and extended classrooms (Clark and Luckin 2013). All of these literacy practices can be seen to be highlighted in the research on mobile technologies and can be seen to be beneficial to many of these practices.

Research notes the social capital and the social and civic benefits that can come with social networking (Ellison et al. 2007). It can be an emotional outlet for school-related stress and validation for creative work, as well as aiding school-related tasks, through group chats and instant messaging. Research has shown that some pupils who may be reticent in speaking in classrooms gain more support when they are able to collaborate with peers outside of this environment and in a space where they feel they can have more confidence without a figure of authority judging their questions and answers (Riddell 2017); these students can seek reassurance through these media and also gain knowledge and expertise from peer-to-peer sharing. Research has linked social capital (that can come with positive Facebook use) with academic achievement.

Correlations have been seen between Facebook use, where Facebook is used creatively rather than passively to check others' posts and look at photographs, and higher standards of traditional literacy used in examinations.

Research into the use of Twitter in higher education shows that Tweeting can allow for real time communication, enable authentic interaction between students and teachers, and provide an opportunity to promote learning (Gao et al. 2012). Microblogging use can expand the learning community and involve a greater range of experts to interact with learning communities. It can help real time reflection on learning practice and enable social constructivist learning. Some research showed its use in arts classrooms where students tweeted as their character in the play (McWilliams et al. 2011), other research suggested that Twitter use reduced isolation and helped interaction among students who were less confident (Gao et al. 2012). As well as a useful administrative tool, microblogging has also been shown to help increase memory for important concepts being taught (Blessing et al. 2012).

Literacy and Meaning Making

However, making meaning is the very bedrock of literacy, whether the definition focuses more on the social and participatory or on the individual and psychological. Despite the focus on the social and participatory above, especially through the lens of New Literacy Studies, there is still a need for theories to study the development of literacy practices in school settings to enable students to make meaning in a variety of learning contexts, especially in relation to digital technologies, and to help students engage with higher forms of learning and academic language and practice. Donald Leu, with the New Literacies Research Team at the University of Connecticut, recognizes the need to build a relationship between New Literacies Theory and the stable and common elements of traditional literacy for new social practices to be efficacious for learning (Leu et al. 2009). Much of his extensive research into digital technologies and literacy development combines

these perspectives and is integral to Online Reading Comprehension Theory (Leu et al. 2009) where he defines reading on the Internet as a process of problem-based inquiry.

Leu points back to the history of literacy (Leu 2006), noting the research of Havelock and others cited above, and notes that cuneiform technologies, papyrus scrolls, hand illuminated Bibles, and the mass publishing of books have all defined the nature of the literacy practices of their periods and all required new literacies to harness their potential. He has stated that the Internet is not a technology issue, but a literacy issue and despite believing that literacy is a deictic construct, ever changing in a technological society, his research recognizes that there are core elements in engaging with the digital technologies seen in the research above, to enable meaning-making to be more successful. He and others from the New Literacies Research Team point to five processes which will involve additional skills and strategies to enable meaning-making and communication: reading to identify important questions; reading to locate information; reading to evaluate information; reading to synthesize information; and reading and writing to communicate information (Leu et al. 2009). In focusing on the idea that the Internet is a literacy, rather than a technology, issue, Leu has emphasized the necessity of embedding such literacy practices as the five points above, across all subject areas in schools. To enable students to become successful processors of online texts, researchers have seen that integrating such practices into curriculum and assessment in schools is highly valuable.

Multiple Documents Literacy

As Leu has shown, reading on the Internet rarely involves reading one text. Research into this area has become known as multiple documents literacy and a number of scholars have proposed models to enable students to become more successful in this field. Jean-Francois Rouet differentiates between “restricted literacy” and “extended” or “functional literacy” which he sees as the ability to use “documents in various contexts and for various

purposes” (2006: 192). Rouet’s work builds on the work of Kintsch (1998) whose Construction-Integration model of reading recognized that successful reading depends on building a textbase model from within the text and integrating it with prior knowledge to create a situation model. Meaning is therefore constructed through three processes. The first process involves encoding words and phrases, this is called the lexical or surface level. The second process, called the textbase level, turns such encoded words and phrases into propositions. The final process is where such propositions are linked to prior knowledge, enabling inferences and implications, known as the situation model level.

Rouet’s work has developed to include research into the importance of domain knowledge for successful text processing and the variety of metacognitive skills needed when processing multiple documents online. These skills can be seen in his MD TRACE model (Rouet and Britt 2011) and developed in further work which highlights the idea of Document Nodes. This work shows that successful processing of multiple documents includes the importance of recognizing source information such as author, date of writing, social context, biases and purpose of writing, as well as the ability to evaluate the content of the document – all these skills combine to create a mental model called a Document Node. A Document Node can link to other Document Nodes which can develop meaning through comparison or contrast, depending on the situation models that are created by the reader from that document. However, researchers note that the complexity of these tasks means that those involved in such literacy practices will need significant teaching and training.

Peter Afflerbach and Michael Pressley have done much work in metacognition, especially in the area of reading comprehension (Pressley and Afflerbach 1995; Pressley and Gaskins 2006; Afflerbach et al. 2015). Much of their work complements the work above seen in Rouet, focusing on strategies to monitor and evaluate text, task, and reader and how these strategies can be taught and modeled in the classroom. Their meta-analysis of research looking at strategies involved in

reading text (just before reading hypertext became widespread) has been instrumental in understanding the metacognitive skills and strategies when making meaning from text (Pressley and Afflerbach 1995).

Following from this research, Afflerbach and Cho (2009) identified strategies used when constructing meaning from multiple texts, under the categories: realizing and constructing potential texts to read; identifying and learning important information; monitoring; and evaluating (2009: 83–84). These strategies were seen to be important for success in this new literacy environment with its many challenges. Separating the strategies into distinct categories with a number of subcategories under each area, Afflerbach and Cho provided a helpful rubric to enable teachers and students to focus on specific strategies that might enable more profitable searching of multiple documents online.

More recent work by these researchers has updated these categories and refined the focus (Cho and Afflerbach 2017). Their continued study in this field has enabled them to divide the process of reading multiple texts online into two main areas, with specific categories and subcategories. These two main areas and their subcategories are given below:

Constructively Responsive Reading Comprehension Strategies for Multiple Digital Texts

1. Identifying intertextual links and making meaning from across texts
2. Monitoring the construction of intertextual relationships
3. Evaluating and sourcing multiple digital texts

Constructively Responsive Reading Comprehension Strategies Used during the Construction of Reading Paths

1. Managing information spaces and navigating toward useful texts
2. Building intertextual linkages and making meanings from hypertexts
3. Monitoring the construction of reading paths
4. Evaluating and sourcing multilayered links and texts

Cho and Afflerbach show that constructing reading from multiple documents can blur the distinctions between reading and writing as the reader is responsible for creating a new understanding and a new text, through the iterative processes seen above. Online reading involves significant self-regulation strategies to enable the reader to stay focused on the goal of the reading and to plan pathways to achieve that goal, despite the many challenges that online reading brings. These challenges include the variety of search engine results, the various genres to be navigated, decisions to choose hyperlinks within texts, and the ability to stay on task despite the hyperlinks being irrelevant to goal though interesting to read. Online reading, therefore, involves a range of metacognitive skills to enable a reader to assemble a coherent mental model from the various Document Nodes created, from the variety of text types and genres being read. This can be both exciting and challenging.

Cognitive Flexibility and Literacy Development

Cognitive Flexibility Theory (Spiro et al. 1988) helps to recognize where this kind of knowledge construction might fit in the process of education. Spiro and others note the difference between introductory and advanced learning and posit that there is an intermediate phase of learning between the rudimentary, simple, and superficial foundational knowledge and the advanced knowledge where concepts can be mastered and knowledge can be understood as more complex and nuanced, context dependent and fluid. Digital technologies and especially multiple documents literacy is perfectly suited to advance learning from the simple to the complex as the Internet is a domain where learners can experience multiple representations of the same topic and recognize that knowledge is not as simple and straightforward as foundational knowledge acquisition presents it to be. In his more recent work, Spiro again emphasizes that cognitive flexibility enables readers of multiple texts to “assemble” understanding from multiple perspectives to forward

deeper, richer learning through making multiple connections and synthesizing relevant information to broaden appreciation for what is being learned (Spiro et al. 2015).

The emphasis on cognitive flexibility for advanced learning can be seen in multiple documents literacy research. The recognition that knowledge is uncertain and evolving is a significant aspect of successful construction of meaning from multiple documents online. The area of epistemic beliefs can be seen across the research as an instrumental aspect to successful meaning-making (List et al. 2013). Researchers have noted that focusing on this aspect can have significant benefits for broader and deeper learning. Braten and Braasch (2018) overview studies focusing on processing texts with conflicting information and outcomes and suggest that where readers encounter such conflicts they are more likely to process the material at a deeper level and with more ability to remember what has been read. This higher-level processing can be seen to be even more marked when the information conflicts with prior held beliefs.

When Spiro points to cognitive flexibility, he recognizes that it is to enable students to move beyond introductory learning and to enable learners to move towards mastery. Digital technologies can enable this more advanced literacy, but Susan Goldman notes that Internet technology has raised the standard for what it means to be literate (Goldman 2015). In the past, a student would not have needed to use such advanced literacy skills until working on research papers at university. At school, there would have been a bounded source of information, from a class or school or perhaps even the community library. The amount of information would have been limited and the evaluation of text authority and accuracy would have been the purview of editors and publishers. Digital technology has changed such literacy practices beyond recognition. Goldman states that literacy has not changed, but our expectations of literacy practices at certain stages of education have changed and expectations have increased exponentially (Goldman 2015: 90, 91).

The Role of the School

David Olson (2009) reminds his readers that the responsibility for developing the literacy needs of young people lies with the school. The responsibility to learn is the pupil's, but he states "Although many agencies have some responsibility for making it possible for learners to acquire literacy skills, in modern societies, the school had been charged with the responsibility for developing those competencies" (2009: 574). Much of the research seen above, not only on multiple documents literacy, but also on digital technologies and applications, has been undertaken with undergraduates. However, if Goldman is correct in recognizing that the expectations for literacy skills that were once the domain of higher education have now been shifted into the secondary sector and for some, even into the elementary or primary years, it is important to contextualize the literacy needs and skills and how to address these in a digital culture that is increasingly part of the school classroom.

Julie Coiro has helped to develop strategies to enable high school students to engage with multiple documents successfully (2011). Her early research with Elizabeth Dobler, in 2006, looked into 11 sixth graders who were skilled and experienced in reading on the Internet. This early work (Coiro and Dobler 2007) helped bring recognition that literacy skills needed for successful meaning-making overlapped significantly with skills needed for print literacy, but also made some processes more complex, such as self-regulated reading and inferential reasoning. In more recent work, Coiro and others have developed an Online Inquiry Tool (Kiili et al. 2016) to help students scaffold their learning online, especially helping with planning, identifying arguments and counter-arguments, critical evaluation, synthesizing information, and composing an argumentative text. This tool is clearly closely linked to the five key elements noted by the New Literacies Research Team seen above and linked to the work of Donald Leu. His continued research has also focused on teenage literacy development in the realm of digital technologies and high school classrooms (Kiili et al. 2012; Kennedy et al.

2016). His work highlights the benefit of working collaboratively to enable higher order questioning and deeper reading and to avoid the more superficial mode where teenagers tend to “locate and gather information” without critically thinking and evaluating. However, Leu recognizes that this collaborative learning and social construction of meaning, though leading to better essay performance, takes significantly longer and can be problematic in classroom situations and especially in contexts where school systems are focused on high stakes testing.

Challenges to Literacy Development from the Digital Culture

Much of the research noted above in relation to literacy development and multiple documents has focused on metacognitive as well as on cognitive skills. However, research shows that these can be impeded by the digital technologies that are an integral part of the culture in which literacy development is taking place (Aagaard 2015). The digital culture can be seen as one of distraction, where research has shown teenagers constantly interrupted from their studies by social media alerts on mobile telephones and computers (Taneja et al. 2015). However, one metacognitive skill that is integral for the ability to construct meaning from what is being read is the ability to attend and monitor what one is reading, especially when there are multiple texts to read or hyperlinks to click or pop-ups that distract in the digital realm. Attention is needed if readers are going to be able to question texts, recognize and repair misunderstanding, and make connection with prior learning and with other texts to synthesize or to recognize counterargument, to read nuance and complexity. Despite the necessity of paying attention to enable comprehension construction and meaning-making, recent studies have found that reading onscreen leads to increased distraction (Baron 2015). Baron surveyed 82 undergraduates and 90% said they were more likely to multitask if reading on screen. Only 1% said that they would be more likely to multitask when reading the information in hard copy. When

given an opportunity to respond to open-ended questions about aspects of reading on screen which they least liked, the respondents volunteered answers which significantly focused on cognitive reasons (91%), complaining that reading onscreen led to greater distraction and a lesser ability to absorb the material. However, research also shows that “the proportion of study time spent attending to relevant information during Internet navigations [is] a significant prediction of retention” (Desjarlais 2013: 701). The research seems to suggest that paying attention on screen is more challenging, yet paying attention on screen is a necessary skill to retain the information found there.

Not only is attention a necessary metacognitive skill which can be more difficult when engaging with digital technologies, but other metacognitive skills can be seen to be affected through technology use. Research into multiple documents literacy shows that prior knowledge can be the single most important factor in meaning-making after decoding. Patricia Alexander and others have noted this in their research and she states that “prior knowledge influences the reading act and is affected by each reading act. So as they read, students are expanding and building their base of knowledge about the world, about texts, and about themselves as readers” (2012: 262). However, research into the cultural reading habits of those immersed in a digital culture shows that much of this general knowledge which used to be gleaned from newspapers and broadcasting is now encountered online, but in a more intentional way (Pariser 2011).

Blogs and forums have been mentioned above as types of new literacies afforded by the democratizing of digital spaces; however, research shows that these are often echo chambers where those of like mind can gather together, rather than places of informed debate with those of different opinions (Poell 2009). Research into the use of social media for electoral campaigning has also shown the targeted nature of such information where those on certain social media sites might never encounter views of a different political opinion (Tambini 2018). Much of the news that teenagers consume is viewed online. Yet here

again there is a further reason why online news might be problematic. The term narrowcasting has been used for the type of news media online users consume and, as a pun on the traditional broadcasting, it differentiates itself from traditional news in that it is self-chosen and self-edited; thus, it can often be narrower in focus. All these platforms allow for a broadening of knowledge and an ability to widen one's understanding of self and the world, but the research shows this might not always be the case and this narrowing of knowledge and understanding of the world has consequences for literacy development (Alexander 2005).

This can be better understood in the light of knowledge gap theory (Trichenor et al. 1970) which suggests that despite the amount of information available in the digital culture of mass communication, it will not narrow the knowledge gap, but expand it. The research shows that those with knowledge, such as political or cultural knowledge, will be able to broaden their understanding and develop their appreciation because of the access to information afforded by the Internet (Wei and Hindman 2011). Foundational knowledge enables more specific search terms and allows for the creation of deeper learning. However, those without such knowledge will be less able to search for more insight; they will be constrained by their lack of foundational knowledge to enable them to create appropriate search terms, critically evaluate what they encounter, or know which are the pertinent hyperlinks to click to lead them into broader understanding. In this respect, the knowledge gap will grow, analogous to the Matthew Effect in language acquisition (Stanovich and West 1989), where those who have, gain more, and those who have little are impeded in their ability to develop their language and learning through less ability to engage with knowledge construction that comes with higher levels of literacy. In their research into knowledge gap theory and the digital environment, Wei and Hindman (2011) concluded that: "...education is the only demographic factor that makes a difference in predicting internet access and information use. ... Besides general education,

training programs that aim to improve people's cognitive skills and internet literacy will be possible ways to reduce the digital inequality" (2011: 28, 30).

This lack of wider knowledge can also have implications for the ability to evaluate sources. The ability to evaluate sources comes from a wider understanding of aspects including source type, publisher, period and context of writing, and knowledge of author. Recent research has shown that students find it difficult to recognize political bias when they are not familiar with the particular leanings of specific news sources (Riddell 2016). This not only has implications for literacy development, but specific political literacy and this can have consequences for the democratic process. Scholars such as List et al. (2013) show that students also tend to choose accessibility of length and content when in time-bound classroom situated tasks, over other more critical ways to evaluate text. This can lead to students choosing self-generated and self-published material with little authoritative value, over more challenging, yet more informative and reliable texts.

As has been seen from the various research above into the cognitive and metacognitive strategies and skills needed for successful processing of multiple documents online, which is the main area where literacy and technology intersect, there is a lot involved in reading online. This too can prove challenging because of the cognitive load that it can bring. Although recent research has begun to look at this area in the light of readers with special learning difficulties, such as dyslexia (Anmarkrud et al. 2018), there is still little research into those with specific challenges engaging with multiple texts online. However, research to date which has looked at competent readers in the digital environment has shown that the variety of tasks involved in strategic processing can lead to cognitive overload (Salmeron et al. 2018).

Cognitive Load Theory was developed by John Sweller during the 1980s. Much of Sweller's work on working memory emphasizes the importance of prior knowledge to reduce cognitive overload (Sweller 1988). Again, this links to the

knowledge gap theory and has implications for our understanding of the relationship between certain literacy practices and certain technologies. Research has shown that cognition can be overloaded even if a person is trying to concentrate on one task to avoid such overload (Nicholson et al. 2005). This research shows that “Empirical evidence indicates that the mental process of ignoring something requires cognitive effort, that is, individuals must constantly remind themselves of what it is that they are trying to ignore in order to expend the effort to ignore it” (2005: 7). This theory can help educators understand the impact on learning if cognition is overloaded due to the amount of distraction in a technologically saturated environment.

Another theory linked to cognitive load that can also play a significant role in understanding the impact of digital technologies on literacy is Lang’s Limited Capacity Model (2000). This aspect of cognitive load theory has been used by many researchers looking into the effect of digital technologies. Although originally based on research into how viewers react to the medium of television (Lang 2000: 47), many of its features are relevant to analyzing the online world. Coiro and Dobler, cited above, showed the relevance of the Limited Capacity Model in their study, when considering what children could attend to when reading web sites and search engines. The model posits that there is a limit to the information that people can process. Lang focuses on three specific subprocesses: encoding, storing, and retrieving. She suggests that resources are allocated to these subprocesses independently and, as a result of these resources being limited, one or more of the processes may suffer if another needs more attention. This clearly has implications for literacy development and researchers have shown how overloading working memory can have consequences for understanding and longer-term memory (Pass et al. 2004). Research into the use of Microsoft PowerPoints in higher education (Worthington and Levasseur 2015) and the design of virtual learning courses (Mayer and Moreno 2003) has shown that serious consideration has to be given to cognitive capacity to ensure that literacy

development is not impeded through cognitive overload due to various digital practices.

Conclusion

This article has shown that literacy and technology are intimately related. Historically, technologies such as alphabetic script, the printing press, the telegraph, and the television have all led to changes in literacy development. Twenty-first century digital technologies are no less integral to literacy practices, as has been seen in this article, whether those practices focus more on the social and relational or more on the cognitive and psychological. Despite the variety of new literacies, many enabled by new technologies, this article has illustrated the need for traditional literacy practices to ensure that citizens have the skills and strategies necessary to succeed in the literacy practices of their choosing. Indeed, this article recognizes that although technologies have enabled new literacies to abound, they have also added challenges to traditional literacy practices that make it necessary for new skills to be learned for successful literacy development, whether in school or in other social practices beyond the classroom. Pitting traditional literacy against new literacies is as unhelpful as pitting technology against literacy. However, for literacy practices to develop and succeed, the challenges as well as the benefits that technologies can bring to the context of literacy must also be realized. When these challenges are taken seriously, technology and literacy can continue to advance together for the benefit of all.

Cross-References

- [Classroom Use, Blended Learning](#)
- [Computers in Secondary Schools](#)
- [Digital Storytelling in Teaching and Research](#)
- [Game-based Learning](#)
- [Mobile Learning](#)
- [Social Media and Networks as Digital Instruction and Learning Platforms](#)
- [Social Media for Tertiary Education](#)
- [Social Networking in Higher Education](#)

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Makerspaces

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Synonyms

[Curriculum for making](#); [Digital fabrication](#); [Engineering education](#); [Innovativeness](#); [STEM](#)

Introduction

The “maker” and “STEM” (Science, Technology, Engineering, Mathematics) movements have recently become an outsize influence in the

discourse around science and mathematics education in the English speaking world, if not globally, not least due to the juggernaut of United States media and business interests’ reiteration of its message (of the confidence in its innovative practices for the future). Part of its appeal must lie in its promises of economic success to the communities that “get it right”, not to mention the human fascination with new devices and technologies that are supposed to lift us from the drudgery of hard work. In this chapter, I seek a different perspective to the essential problems of science education and propose how educators may meaningfully integrate a design and engineering perspective to learning, idiosyncratic school system concerns notwithstanding. In essence, there is a truly novel challenge being posed by the STEM and maker movements and the technological progress that they represent – the uniquely human ability for insight and knowledge generation compels us to consider deeply how we can teach students to make new knowledge. Some perspectives on the nature of knowledge and learning are used here to develop a case for what this form of learning ought to achieve and what it may look like.

Exciting Times Ahead?

Simply judging by the approximately 600,000 Google Scholar search results for “maker movement” in January 2018, it is probably an understatement to claim that the movement has attracted widespread attention around the world. The outsize influence of

the Californian economy, specifically its high technology sector and their seemingly effortless process of creating money out of thin air have no doubt been significant sources of inspiration for teaching and learning. It can be easy to agree with claims that we are in a new information age, given the ease and ubiquity with which information is stored, retrieved, and manipulated. The manner in which designs are created, exported, made ready for manufacture, shared, and reused have concomitantly ridden upon this information age; interesting technologies have also emerged surrounding the fabrication and manipulation of materials, all of which appear to point to bright shiny futures indeed for any and all who will join the campaign. Yet, as they say, not all that glitters is gold. For economies seeking to replicate the success of California's Silicon Valley, the reductionist approach of finding the "active ingredient" of a particular approach to education and applying it like a salve to another patient will encounter the complexity of educational interventions – where all "layers" of analyses, from the cognitive to the sociological, interact nonlinearly and matter. This is, essentially, a curriculum question, and depending on one's perspective, it can be heartbreaking to learn that despite changes to social circumstances over many decades, the fundamental relationship of schooling to societies has, in many ways, not changed significantly. However, this observation should not prevent our attempts to actually do so; always carefully paying attention to the educational problem first and not attempting to bring technical solutions in search of problems to fix.

The problem with curriculum arguments that originate outside of educational circles may be a lack of understanding of the educational context. It is not uncommon for business leaders to lament that schools need to be run like businesses, badly underestimating the level of challenge posed by public schooling (Cuban 2004); yet we see no end to wealthy individuals and corporations insisting (at least in the United States) that they get their tax dollar's worth of learners prepared to enter vocations in their industry; in that regard, the current discourse around twenty-first century competencies do not sound very different from the shrill scare-mongering of "unilateral educational

disarmament" of the 1980s (Bracey 2003; Gallagher 2013; National Commission on Excellence in Education 1983). The point of the foregoing is to direct the reader's attention to the fact that education is a heavily contested political ground, and that it is not uncommon for societies to demand that schools solve all manner of social problems (Labaree 2008), including those of individual and communities' successful participation in future economic activity. Often, these problems are not education's to solve – there are far greater factors determining success than purely one's preparation for the world of work. We should rightly be sceptical of efforts to foreground STEM in the classrooms simply because of some variant of "the future demands it". Unfortunately, as Burbules (2016) points out, we in education appear to have an occupational hazard: because in our working with growth and change, it becomes second nature that we celebrate newness. Because of the apparently unceasing nature of technological "progress", it becomes virtually inevitable that technologies become perceived as possessing particular pertinence to "solve" all manner of problems, real or imagined. Yet, if the history of technology in education has any bearing, there is no shortage of well intentioned technologies which promised to revolutionize schooling, but have not (Cuban 2001). The risk for our moment in time is no different; and in some circumstances, it is easy to discern the formation of an unsustainable bubble of hype. The fundamental challenge that can be posed by technological interventions need to be considered at the level of the cultural – if the hypothesis of a certain "law of amplification" holds, we need to understand changes to practices as only being amplified by technology, and that the hard work of changing practice needs to precede its amplification (Toyama 2015).

Rather than jump onto the bandwagon of making, makerspaces, and STEM education, it is important here to consider what may be truly innovative and meaningfully pertinent to science education, keeping in mind its persistent problems. The strategy for this chapter is to convince the reader of the nature of the educational problem

generally speaking, and the futility of universal solutions. This situation arises out of the nature of solutions to social problems. Having said that, however, it can be possible to unironically claim that there is nonetheless a certain subclass of problems, which confronts learners of the natural sciences. These problems arise out of the nature of the knowledge itself. It is then upon the local implementers of curriculum to carefully design learning goals, contexts, and methods to achieve locally sufficient solutions that take into account ontological and epistemological constraints of knowledge in the natural and *artificial* sciences.

Curriculum Problems Are Wicked Problems

When carefully considered, the advocacy of STEM education, making, and makerspaces needs to be thought of as a curriculum proposal. Proponents of STEM are essentially claiming that, among other things, students ought to learn STEM, how to make things, and that there ought not to be distinctions between the knowledge forms. Not surprisingly, at least popular proponents have pointed to the success of the Californian economy, ostensibly based on STEM innovation, or innovativeness in general, as a reason to adopt the practices of its most successful exponents. While there may be good reasons to suppose that some of these practices are truly novel and contributive to economic success, there are also significant reasons to be sceptical of some of the more excessive claims. California and the United States in general have been the beneficiaries of a particular confluence of conditions that are historical contingencies and not easily replicated anywhere else in the world. Not having one's infrastructure destroyed by massive wars and being able to attract the world's intelligentsia in the process are certainly helpful conditions for success. What is perhaps less well known, but not less important, is an ability to selectively ignore the contradictions and hypocrisy of advocating a self-reliant "bootstrapping" mindset, while remaining silent about the huge

handouts from the military-industrial complex; or advocating a belief in the emancipatory potential of new information technologies, while simultaneously being responsible for "technologies of freedom [...] turning into the machines of dominance" (Barbrook and Cameron 1996).

This is not to say that there is a lack of meaningful forms of knowledge that can be used in different contexts, but rather that there ought to be a careful adaptation and use of principles derived from one context, in another. For instance, Lindtner and associates (Lindtner 2014, 2015; Lindtner and Lin 2017) document, among other things, that indigenization processes modify the supposed participatory ideals of making to suit idiosyncratic political projects; that making can become discriminated into craft-hobby versus industrialized versions; and that maker culture can provide opportunities for people to creatively reinvent visions of self, not necessarily constrained by existing public discourses. Making in public makerspaces has also been documented as not being very much distinct from serious leisure pursuits (Stebbins 2009) such as gardening or carpentry (Davies 2018; Toombs et al. 2014). The problem for education here is to discern whose vision and values of what STEM and making constitutes is most appropriate for schools – why, for instance, should a school focus attention on a particular device or engineering sub-discipline when the local industrial community is more interested in solving other kinds of problems? Significantly, the general form of this problem is that of the wicked problem (Borko et al. 2008; Coyne 2005; Rittel and Webber 1973): essentially intractable, lacking in general solution, only amenable to case-by-case "good enough" transient solutions that create their own follow-on problems. Curriculum solutions, as with many solutions to design-based problems involving numerous competing interests, are inevitably wicked, and necessarily involve compromises to achieve stated or actual goals. The task for the educator considering making is to strike a locally acceptable compromise; to that effect, what follows are some possible goals and their costs and benefits.

Making for What?

Perhaps the most intuitive application of making and makerspaces is as a site that may ostensibly serve as a means to get students engaged in the learning of STEM. Here, making in itself is likely to be perceived to be of somewhat lesser value to the acquisition of STEM curriculum goals. Making could also be used as a means to acquire aspects of (functional) design and engineering competence, and also as a way to demystify technological devices. In concert with the arts, the moniker of STEAM (STEM with the Arts), the creation of aesthetically pleasing interactive art objects can serve the goal of weakening the boundaries between disciplines. Indeed, there has been much clamor for such forms of weakening, especially with the rise of “design thinking” as legitimate curriculum goals. Design, as a relative newcomer and out of place in contrast to the traditional disciplines that define school (broadly, literacy and numeracy), is likely to pose significant challenges to traditional schooling due to its loose boundaries. Design competence can take the entire gamut from architectural, engineering, fashion, and so on to many others. However, it may be useful to note that design leaders offer broad characterizations of good design as meeting at the confluence of “technical feasibility, social desirability, and business viability” (Kelley and Kelley 2013), or that design competence requires designers to make what are essentially value judgements, prescriptive statements of what ought to be, that are necessarily distinct from descriptive statements of what is (Nelson and Stolterman 2003). Learning design and making requires a certain reimagining of the curriculum boundaries of schooling – while it is not science, not art, not anthropology, nor sociology, it draws from these rich disciplines and transcends them through a creative process that does not originate from any of these disciplinary bases. On the other hand, while it can be easy to get caught up in the buzz surrounding “design thinking” as the contemporary equivalent of “scientific thinking” in times past, it is nonetheless important to acknowledge the intellectual debt owed to the “traditional” disciplines. Without an accurate apprehension of

the nature of reality as revealed by the natural and human sciences, it would be much harder to make value statements about how an ideal design ought to be. The response to “Why make?” could take the form of three purposes: as a context for learning; as a means to acquire design competence and dispositions; and as a means to learn about the gap between theory and practice. These will be elaborated as follows.

Making as a Context for Learning

As mentioned, this approach to making is perhaps the most common and intuitive to educators. The contemporary tools and technologies present unique affordances to schooling that may provide opportunities for forms of learning only previously dreamt of. As with revolutionary information and communication technologies that have changed the way learning may be facilitated, proponents of making with contemporary tools suggest that these tools can, among other things, serve as a form of “Logo, for atoms” (Blikstein 2013; Martin 2015). They refer to the computing tool, Logo, designed to teach programming by having its users take control of a symbolic turtle, and providing instructions to cause the turtle to move in various ways. The kind of learning privileged here may be aptly summarized by the quote attributed to Seymour Papert: “Constructionism shares constructivism’s connotation of learning as ‘building knowledge structures’ irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it’s a sand castle on the beach or a theory of the universe” (Papert and Harel 1991). With making, an instructional approach could be to create structured opportunities for students to confront the limits of their own theoretical structures. This could take the form of investigative activities that capitalize on students’ curiosity, by introducing discrepant events that challenge students’ perceptions of what constitutes “normal” physical behavior (Lawson 2010). Such an approach is certainly not new (White and Gunstone 1992); what is more novel is perhaps the manner in which we now are able to hand over to students

the “means of production”, in that the flexibility and capability of tools available to students allow for significant student input into the experimental design and the possible range of parameters. While in the past teachers may have been limited to setting up experiments with data loggers and their proprietary sensor probes, a contemporary microcontroller can accept a wide range of inexpensive sensor modules, and be open to more fine-grained control and programmability using programming environments which allow for such features. If the learning goals for such kinds of making remain the acquisition of expertise in traditional pen-and-paper standardized assessments, there stands a significant risk that these activities will not go far enough to change the shape of schooling. While this might sound obvious, the conservative capacity for school systems to remain unchanged should not be underestimated. At some level, the lower ambition models of instruction in making may resort to versions of the so-called “keychain syndrome” (Blikstein 2013), so called because a common first activity for students learning 3D printing is the production of keychains with their names or personalization on it.

The expansion of goals of schooling to also include some form of understanding about the functioning principles of technological devices needs to be considered an important goal of advocacy for STEM and making. However, such an approach needs to be carefully considered. The political costs of dedicating limited school time on learning technologies that have no future relevance can be high enough to cause administrators and educators alike to stick to “tried and true” conservative goals. Considering the recent history of trends in technology, it is not hard to notice patterns of increasing hype and rhetorical urgency about the necessity of equipping our youth for a future of computers, microelectronics, genetics, internet applications, and game design. Equally predictable has been the gradual fade into the background as the Next Big Thing arrives. It should not be surprising that, as Cuban (2001) surmises, the rational strategy for administrators would be to simply button down and wait for the storm to pass. Such an approach is certainly not

completely defensible, but the form of this argument, in seeking the verities “eternal, changeless, possessing a certain indefinable and imponderable something whose essence is timelessness” (Peddiwell 1939) is definitely not new. While we may leave the curriculum theorists to debate on the nature of knowledge, a provisionally acceptable position for this problem may be advanced: we ought to educate students about technology, sufficiently that they may be empowered enough to be more than its casual users, but not so much as to lose sight of the transient nature of technological tools. The goal, if we were to adapt Arthur C. Clarke’s (1977) dictum that “Any sufficiently advanced technology is indistinguishable from magic”, must be to empower individuals to demystify these boxes of magic. Here, approaches deriving from the hacker mindset of getting down to the bottom of things, to metaphorically and literally opening up the boxes, to reconsider how particular implementations of ideas can be altered, adapted, and improved (Bratus 2007; Grand 2006) can be useful indeed. Extending the black box analogy, it may be useful to consider the goal of this form of education as developing in students the dispositions and abilities required to inquire into the inner workings of black boxes, and to develop models and functional equivalents to *classes of devices* of interest, rather than to necessarily become connoisseurs of one specific device. With little doubt, this will involve students gaining expertise in one instance of a device; however, it should be considered incomplete if this is all that is acquired. To be sure, one aspect of the “hacker mindset” – that of only needing to be “good enough” for the task at hand – can be detrimental as a learning disposition. If we wish to educate students so as to expand the boundaries to which they may take action in the future, we may want them to know that there are problems for which prior solutions have been considered, and that there is no need to reinvent the wheel every time an apparently new problem arises. Ultimately, this remains a core tension of learning: the balance between the need to reproduce culturally significant forms of knowledge and nurturing the ability to create new ones to respond to problems as they arise.

Making to Acquire Design Competence

Design expertise can be mysterious in no small part due to its rather recent heritage compared to the more established disciplines. As alluded to above, design is a transdisciplinary practice, in that it draws from diverse disciplines to arrive at a set of insights with emergent properties that may not be predictable from a pure study of the disciplinary bases. For instance, while antenna design for smartphones is ruled by the physics of microwaves, nothing in physics could have prepared designers for the manner in which telephones were held; similarly, nothing from human factors study could have predicted the magnitude of signal attenuation caused by human flesh in contact with radiating antennae. If we were to expand the scope of design to cover all manner of possible designs, covering the gamut of knowledge from architecture to zoo habitat design, it would seem impossible to characterize the diversity of expertise for designers. Nonetheless, if one were to take the wide view, it may be possible to discern patterns uniting acts of design. In common, design studies form a science of the artificial (Simon 1996), in that design's interest is in the interface between the goal that humans may intend for an artifact to solve, and the internal mechanisms that may bring about the goal. Such behavior is perhaps the defining characteristic of human and sentient tool use: a concern for bringing about the solution of a perceived problem in a manner consistent with a particular desire, and a method of selectively organizing phenomena in a hierarchical manner to bring about the desire. For instance, while a smartphone is a complicated mechanism, the operating system designer can do his work without much knowledge of the exact functioning principles of the processor integrated circuits (Although the recent Spectre and Meltdown malware attacks point to a possible vulnerability in this line of thought.). In what must seem like a contradiction to the advice above, it can be perfectly acceptable for designers to ignore the details at a deeper level. To be sure, such a practice is also routinely carried out in entire disciplines of the natural sciences: ecological behavior can be studied with little knowledge about the chemical functioning of the individual

organisms, let alone the atomic interactions that make up the biomolecules. The point here is that the process of design can be thought of as the manipulation of sufficient layers of complexities as needed to cause desired changes at the level of interest. A manner of thinking that can abstract the pertinent details, while ignoring those that do not matter to the problem at hand is central to the ability to control sufficient complexity to achieve the designer's desired goals.

For instance, the development of circuit tiles or equivalent means of rapidly connecting electrical and simple electronic circuits can quickly abstract details away from novices, the goal of which could be the acquisition of an overall sense of how devices could be built up using electronic elements. Such systems utilize magnets, physical interlocking shapes, or other means to ensure that circuits cannot be misconnected, and hence reduce complexity of the learning task for students. By treating each circuit element as a black box, and selectively probing these elements to discover what they do in concert with other elements, students can be free to make circuits that fulfil particular functions, rather than be bogged down by the details of the specific limitations of how electronic elements have to be connected in particular ways. In this sense, the timeliness of the maker movement has been aided in no small part by numerous technologies that have increasingly obscured the internal workings of devices, in exchange for a supposed gain in users' abilities to achieve design goals. Website authoring tools, three dimensional (3D) printing, and the entire movement of downloadable designs leading to adapted designs, digital photography and videography: all these and other technologies offer users the Faustian bargain of an ease of use so as to focus on the emergent layer of intentionality. The flip side, however, is the common refrain that the "younger generations" no longer have the aptitude for repairing things, and is also somewhat ironically a motivating call for the STEM/Maker movement. In a sense, such a critique is somewhat unfair, as the devices and systems being manufactured for sale are seldom serviceable by hand, and manufacturers, often motivated by profit, are placing barriers in the way of

repairability. Nonetheless, the critique is in the right direction, either for environmental reasons (owing to the finiteness of material resources), or for demystification and empowerment reasons as mentioned above.

Making as Performance

Perhaps least-well elaborated theoretically, but most often intuited as a significant reason for supporting making and the STEM movement, is the performative aspect of knowledge. Here, attempts at identifying the phenomena include the notion of the theory-practice gap, the realization of the importance of tacit knowledge, and more recently, attempts to explain learning from an embodied cognition perspective (Barsalou 2010; Goldinger et al. 2016; Shapiro 2007). The central tension here is between knowledge-as-representation, and knowledge-as-performance; or, as observed by Gilbert Ryle over 70 years ago (Ryle 1946) the distinction between knowing-that and knowing-how; or, being able to know more than one can tell (Polanyi 1966/2009). It would be fair to say that, with the relative ease by which a representational assessment may be conducted via a paper and pencil task, the demands for efficiency of school systems have largely made this form of assessment and instruction the default mode. For a time, such an approach was easily the preferred mode, as it seemed that the higher paying jobs were being reserved for the people with competence in symbolic rather than material manipulation. Yet, with increasing automation and the slow but inevitable creep of symbolic processing technology into the workplace, it is hardly surprising to learn about the contemporary capabilities of such technologies (Carr 2015), and the goals toward which they have been put. It appears that the financial incentive to remove highly trained artisanal labor, (be they expert wheel builders, burger chefs, or more recently, radiographers), and replace them with a serial process of arbitrarily small steps each accomplishable by the lowliest paid unit, is simply irresistible to capitalists (Crawford 2009). This process of “cognitive sedimentation”, as Crawford calls it, appears to affect any kind of work process that is routinized; ultimately, it may have its roots in the Western line of thought that

finds it natural to have a dualistic separation of mind and body, form and substance.

This line of thinking can be referred to as *hylomorphism*, “from the Greek *hyle* (matter) and *morphe* (form). Whenever we read that in the making of artefacts, practitioners impose forms internal to the mind upon a material world ‘out there’, hylomorphism is at work” (Ingold 2013, p. 20). It is easy to fall into the trap of hylomorphism, especially since the promise of mass industrialization is, at least in part, the widespread accessibility of extremely sophisticated material designs brought about by the low cost mass reproduction of well designed plans to make them. It is hylomorphism at work when we see products labeled as being designed in one place, and manufactured in another. Yet, what is hidden from view is the expertise necessary to process materials to make these designs a possibility. These forms of expertise are precisely the kinds of expertise that engineers involved in manufacturing wish to preserve as their own and to distinguish from the kind of craft-based, one-off “making” more commonly associated with makerspaces (Lindtner 2015). Nonetheless, the intent here is to attempt to distinguish between manufacturing, an industrialized process of duplicating, and *making*, a more limited and creative performance that blurs the boundaries between form and substance, design and material, and subject and object. The contention here is, as with Ingold (ibid.) and others, the activity of making is necessarily a contingent process where the intended outcomes of the process of making is always inseparably connected with the trajectory of materials in their process of becoming.

While this may sound counterintuitive from the perspective of limited public understanding of the design and manufacturing processes, such an anti-hylomorphic interpretation of the processes of *doing* science may underlie a more accurate understanding of the tacit knowledge of science. In what Pickering (1995) refers to as the *mangle of practice*, scientists are always in the process of adjusting their goals (a process he refers to as accommodation) in response to resistances encountered in the pursuit of their scientific claims. In a follow-up volume (Pickering and

Guzik 2008), examples are fleshed out, of scientists who, especially because they are working at the boundaries of our knowledge, struggle continually with materials which continually resist the efforts of scientists to derive abstracted systems of representing and predicting their experiences with these materials. For instance, attempts to model, understand, and control the flow of rivers have resulted in no end of disappointment and loss of resources and even human lives as nature repeatedly reveals more and more ways to defy the human capacity for control. Pickering (2008) goes as far as to suggest that a new ontological metaphor for the natural sciences needs to be considered: from one of a project borne out of attempts to reveal the hidden secrets of nature so as to control it; to one where humans learn to take a mutual dance of agency with nature. As with dancing, the process needs to be interpreted as a mutual, *performative* give-and-take between the parties of human and material agencies as scientists learn how to accommodate impossible-to-anticipate material interactions within their explanatory frameworks.

The outcome of this line of reasoning compels us to rethink our curriculum priorities when it comes to the STEM disciplines. If the performance of science is to be considered at least as important as one's facility with its canonical representations, rudimentary expertise in purely technical procedures already part of typical programs in science will not be sufficient. How it is that we may be able to arrive at new knowledge claims, and the partial, interpreted nature of the behavior of natural systems needs to be a focus. While inquiry approaches have recently captured the attention of the science education community, perhaps less investigated is the role of human interactions with material agency in this process: how should educators, for instance, capitalize on the opportunities presented to learners when experiments do not proceed as planned? What opportunities for learning in science are missed when we insist on standardized materials, methods, and equipment to obtain canonically acceptable depictions of natural behavior? What other forms of scientific performances ought to be valued if we are to consider

this alternative ontological metaphor for the pursuit of scientific knowledge?

Conclusion: Is Making an Educative Activity?

It would be too glib to repeat the words of the more famous popularizers of making as an intrinsically learning activity (of which there are plenty); and yet too facile to say that the educative value of an activity ultimately lies in its instructional accompaniment. As for the complex phenomenon that education is, there are several interpenetrating layers for consideration that ultimately determine the ideal end state of our venture: that people learn. On one level, the sociocultural organizational patterns of making resemble sites where innovative making and design can be used, either to prepare students for potential sites of future work, or as actual alternatives to industrial-rational practices of schooling conventionally practiced. On yet another level, the psychological insights that one may obtain from a direct and physical interaction with a material reality can offer to students perspectives that are simply not possible to obtain through mediated forms of experiencing. Finally, the gains to society from communities who are empowered to understand the functioning principles of the background technologies that support their very existence needs to be considered a vital prerequisite of being a responsible, fully participating member of society. The question that ought to confront us now is how soon these practices can become as synonymous with education as the classroom and the blackboard currently are.

Cross-References

- [Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption](#)
- [Empowerment and Disempowerment in Peer Observation Within Pre-service Teacher, Technology-Assisted Integrated STEM Education](#)
- [Mathematics Education and Technology](#)
- [Science Education and Technology](#)

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Malaysian Smart Schools

► [Computers in Education in Developing Countries, Managerial Issues](#)

MAPLE Computer Algebra System

► [Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption](#)

Mathematical Learning

► [Mathematics Education and Technology](#)

Mathematical Teaching

► [Mathematics Education and Technology](#)

Mathematics Education and Technology

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Synonyms

[Computer-based mathematics learning](#); [Digital learning in mathematics](#); [Digital teaching of mathematics](#); [Mathematical learning](#); [Mathematical teaching](#); [Technology-enhanced learning in mathematics](#); [Technology-enhanced teaching in mathematics](#)

Introduction

Recent international surveys such as the Organisation for Economic Co-operation and Development (OECD) report *Students, Computers and Learning* (2015) highlight the wide gap in students' access to, and use of, technology in

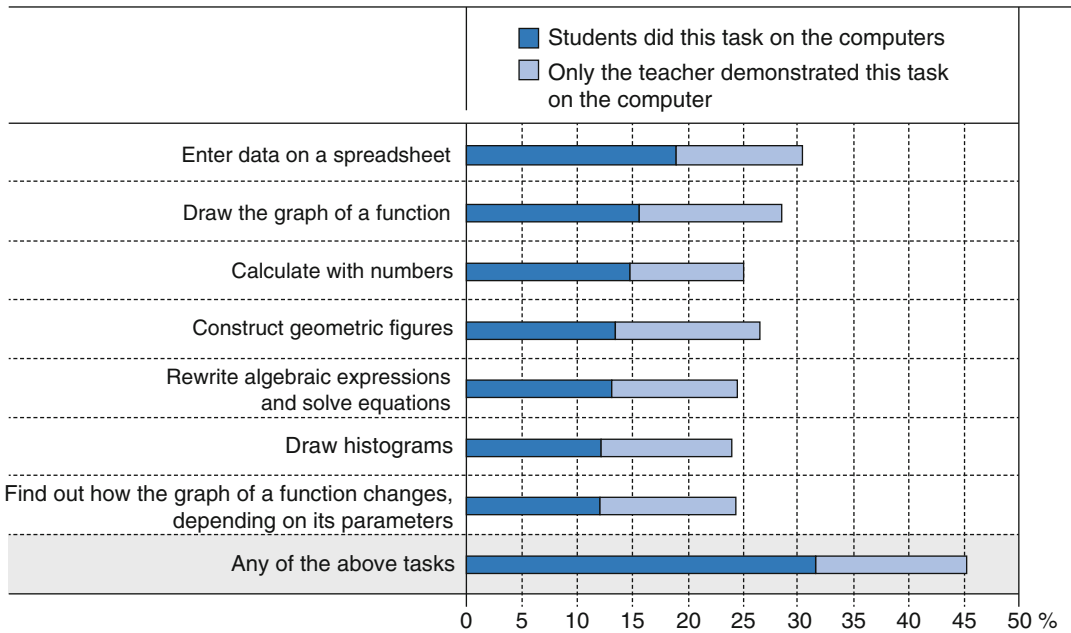
secondary mathematics in participating countries. The OECD “snapshot” methodology in which 15-year-old students were asked if they (or their teachers) had performed a range of mathematical tasks using computers in the month preceding their completion of the Programme for International Student Assessment (PISA) survey revealed low levels of technology use (see Fig. 1).

However, these data revealed big differences between countries. For example, in Norway, 73.1% of students reported at least one of these uses of technology, whereas for Ireland, the figure was 17.6%.

While the OECD reports teacher and student usage, it gives no insight into the context in which this usage is taking place. A country's (or region's) policy for technology use in its mathematics curriculum (and the associated assessment regime) has long been cited as a potential catalyst or barrier to technology use (Hoyles and Lagrange 2009). For example, mandating technology use in examinations is a known factor that increases classroom usage by teachers and students. This article aims to reveal similarities and differences between the international policies and practices as a means to shed more light on the OECD data. There are two important caveats:

- National curriculum and assessment policies are dynamic, with varying timescales for review and implementation. As this study reflects the current picture, it cannot be assumed that the 15-year-olds that took part in the PISA study experienced the curriculum and assessment regime as reported.
- In some countries such as the USA, Australia, and Germany, there is wide regional variation due to locally mandated curriculum and assessment policies.

The categories used in the OECD survey reflect the international evolution of how technology is now being used within mathematics education. The following entries of the Springer Encyclopedia of Mathematics Education expand on the evolution of these uses with respect to technology types and design considerations



Mathematics Education and Technology, Fig. 1 OECD average use of computers during mathematics lessons (OECD 2015, p. 56)

(Freiman 2014a, b), the affordances of technologies for mathematics education (Hegedus and Moreno-Armella 2014), and the implications for mathematics curricula (Sutherland and Rojano 2014).

Technology is interpreted as a mathematical “tool” that offers a mathematical environment within which to explore, express, and communicate mathematical ideas. (For more on mathematical digital tools, see Monaghan et al. (2016).) Hence, it has many uses within the design, teaching, and assessment of mathematical activity, which form the main focus of this text.

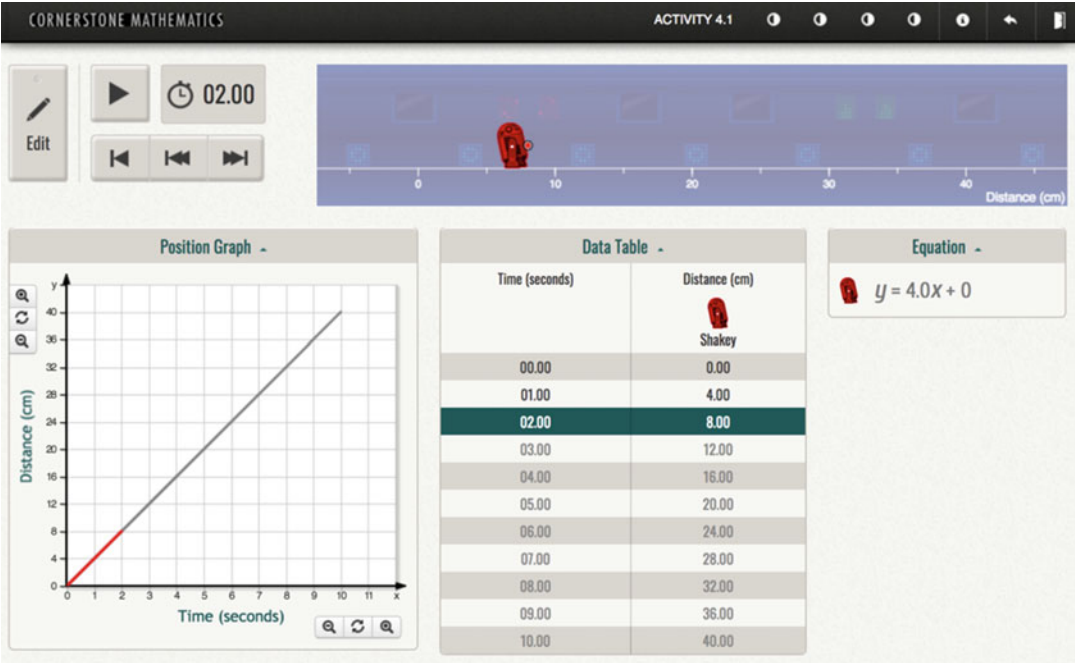
As an example, consider Figs. 2 and 3, which show a digital resource for lower secondary students that aims to provide them opportunities to “Find out how the graph of a function changes, depending on its parameters,” one of the seven task types that feature in the OECD survey. In Fig. 2, the character “Shakey the Robot” has been animated to travel along the number line in real time. Simultaneously, the character’s position-time graph is plotted and the corresponding data-line highlighted in the table. The linear function that describes the motion algebraically is also

given in the form of an equation. Figure 2 is a “snapshot” of this motion when the lapsed journey time is equal to 2 s.

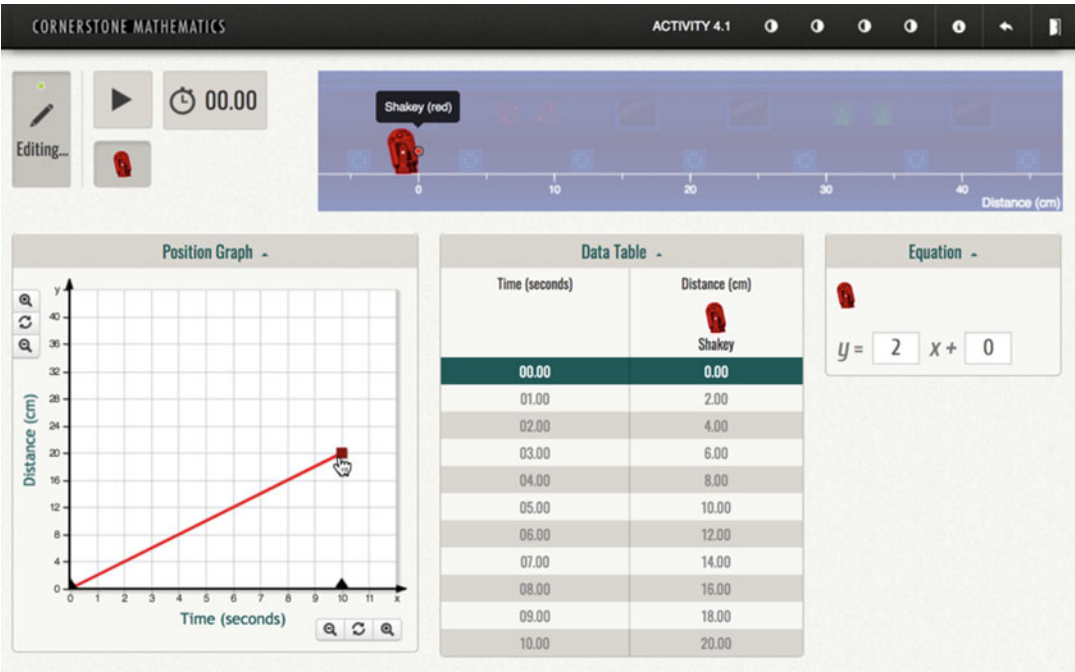
In Fig. 3, the simulation is shown in edit mode, which affords the student the choice to vary a number of parameters (start position, finish position and speed) by dragging hotspots or changing numerical values.

This resource, which is taken from the Cornerstone Maths linear functions curriculum (www.ucl.ac.uk/cornerstone-maths), has its antecedents in the work of Jim Kaput in the USA and has been extensively evaluated with positive impacts on students’ mathematical outcomes in a number of studies in the USA and England (Hegedus and Roschelle 2013; Hoyles et al. 2013; Kaput 1989; Kaput and Schorr 2008).

An alternative technology might be to use an online graphing tool such as Desmos (<https://www.desmos.com/calculator/56envakzbp>), a graphing software package or a graphical calculator. There is consistent research evidence to suggest that such technologies support students’ understanding of the function concept (Kieran 2014), although it is important



Mathematics Education and Technology, Fig. 2 “Shakey the robot” – a snapshot of an animated journey



Mathematics Education and Technology, Fig. 3 Shakey the robot – editing the animation

to highlight the key role of the teacher in the successful integration of such technologies in classrooms (Clark-Wilson et al. 2014). Consequently, this article also sheds light on the policy and practice concerning initial and in-service teacher education for technology use in mathematics in the different countries.

Although the main tenet of the article is focused on upper secondary education (14–19 years), it begins with a brief commentary on the policy differences regarding primary (4–9 years) and lower secondary education (9–13 years) as indicators of the varying trajectories of students’ experiences through their schooling.

Technology Use in Primary Mathematics Education

The majority of the 16 countries (or regions) do not mandate for the use of mathematical technologies in the primary mathematics curriculum, although the use of general, non-specified technologies is sometimes required. The exceptions are France, Portugal, Norway, Wales, and the state of Victoria in Australia.

Table 1 shows the distribution of countries and their technology use.

The French national curriculum includes a particularly forward-looking vision statement, which translates to:

The school contributes to the project of a society of information and communication for all by initiating, in partnership with communities and different actors, actions to generalise uses and develop digital resources for education. It trains students to master these digital tools and prepares the future citizen to live in a society whose technological environment is constantly evolving. (<http://www.education.gouv.fr/pid24307/les-programmes-de-l-ecole-elementaire.html>)

This vision is supported by a government department, the “Digital Education Directorate,” which provides links and resources for teachers to realize this aim. Furthermore, all trainee teachers in France are required to pass a Master’s level course on the use of technology for teaching and

Mathematics Education and Technology, Table 1 Tech-nology use in primary mathematics education (5–8 years)

	Technology use is mandated in the national/ regional curriculum	Technology use is optional in the mathematics curriculum
No standardized high-stakes testing	Australia (Victoria)	Germany
	France	Netherlands
	Norway	
Students can choose to use technology in some or all high-stakes mathematics assessments		Israel
Students are not allowed to use technology in any high-stakes mathematics assessment	Portugal	England
	Slovakia	Hong Kong
	Wales	Ireland
		Italy
		Scotland
		Taiwan
		Turkey

learning, although for primary phase teachers, this might not necessarily have a mathematical focus.

In Norway, a similar broad vision for mathematics exists that encompasses the role of digital skills:

Digital skills in Mathematics involves using digital tools to learn through play, exploration, visualisation and presentation. It also involves learning how to use and assess digital aids and tools for calculating, problem solving, simulation and modelling. It also means it is important to find information, analyse, process and present data using appropriate tools, and being critical of sources, analyses and results. The development of digital skills involves working with complex digital texts with an increasing degree of complexity. It also involves developing an increasing awareness of the new digital tools that exist for learning in the subject of Mathematics. <https://www.udir.no/kl06/MAT1-04?lplang=http://data.udir.no/kl06/eng>

Within the primary curriculum, this vision is exemplified within one of the content statements for geometry, where pupils are enabled to “make

and explore geometric patterns, with and without using digital tools, and describe them orally” (ibid.).

The approach to the assessment of primary mathematics varies internationally. Some countries require classroom-based teacher assessment (e.g., France, Norway), whereas other countries conduct high-stakes examinations at a national or regional level (i.e., England, Netherlands, Hong Kong, Singapore, Slovakia, Taiwan, Turkey, Wales). For those countries with high-stakes testing, none permit the use of technology by primary students.

Technology Use in Lower Secondary Mathematics Education

In the lower secondary phase (9–14 years), there is a shift to more mandated use of technology in the mathematics curriculum, with several countries typically specifying the use of spreadsheet, function plotting, and dynamic geometry software applications (i.e., all states in Germany, Portugal, France).

Table 2 shows the distribution of countries and their technology use in this education phase.

Again, some countries have offered a more visionary stance, such as Portugal:

All Secondary Schools must equip themselves as soon as possible with Mathematical Laboratories. The didactics for Mathematics in secondary education presupposes the possibility of using diversified materials and equipment: graphical calculators with the possibility of using programs; computers; data collection sensors for both calculators and computers. It is considered indispensable to use: graphing calculators (for regular classroom work or for demonstrations with all students, using a “view-screen” calculator); a computer room with software suitable for work as regular as possible; a computer connected to a data-show or video projector (for demonstrations, simulations or classroom work with all students at the same time). (Ministério da Educação e Ciência 2001, pp. 14–15)

In this phase of education, the shift is toward optional use of technology within mathematics assessments, which seems to accompany more explicit curriculum guidance for its use. The trend is to permit the use of scientific and/or graphical calculators within high-stakes testing.

Mathematics Education and Technology, Table 2 Technology use in lower secondary mathematics education (9–14 years)

	Technology use is mandated in the national/ regional curriculum	Technology use is optional in the mathematics curriculum
No standardized high-stakes testing	Australia (Victoria)	Netherlands
Students are mandated to use technology in some or all high-stakes mathematics assessments	Norway	
	Portugal	
Students can choose to use technology in some or all high-stakes mathematics assessments	France	Hong Kong
		Ireland
		Israel
Students are not allowed to use technology in any high-stakes mathematics assessment	Slovakia	England
	Wales	Germany
		Italy
		Scotland
		Taiwan
		Turkey

Some countries are in the process of reviewing the role and use of technology in this educational phase. For example, in Ireland, the forthcoming introduction of an element of classroom-based assessment in mathematics during the “junior cycle” is expected to stipulate the use of digital technology – especially for statistical investigations. The influence of “big data” in wider society seems to be affecting attitudes to technology use in mathematics education as the need to develop students’ mathematical and statistical thinking through more open exploration and modeling of large data sets gains importance.

Technology Use in Upper Secondary Mathematics Education

Unsurprisingly, most policy guidance on technology use with respect to the curriculum and its

Mathematics Education and Technology,
Table 3 Technology use in pre-university mathematics education (14–19 years)

	Technology use is mandated in the national/ regional curriculum	Technology use is optional in the mathematics curriculum
Students are mandated to use technology in some or all high-stakes mathematics assessments	Victoria, Australia	
	Germany	
	Netherlands	
	Norway	
	Portugal	
Students can choose to use technology in some or all high-stakes mathematics assessments	England	Hong Kong
	France	Ireland
	Slovakia	Israel
	Wales	Italy
		Scotland
Technology use is not permitted in assessments		Taiwan
		Turkey

assessment is visible in the upper secondary phase, which coincides with the age range of the students who participated in the OECD survey.

The distribution of countries is shown in Table 3.

At this educational phase, several countries’ curricula refer explicitly to the (mathematical) affordances of the technologies that students should use. For example, the Welsh curriculum states:

At Advanced level, calculators must include the following features:

- An iterative function;
- The ability to compute summary statistics and access probabilities from standard statistical distributions.
- And they must not, for example, be designed or adapted to offer
 - Symbolic algebra manipulation;
 - Symbolic differentiation or integration

(Welsh Joint Education Committee 2017, p. 39)

Alternatively, other countries’ curricula offer a set of mathematical-technical competencies that students should acquire. For example, in Norway, students are expected to be enabled to: “perform,

describe and provide rationale for geometric constructions using a compass and ruler and dynamic geometry programs” in geometry; and “prepare functions that describe numerical relationships and practical situations, on paper and digitally, describe and interpret them and convert between various representations of functions, such as graphs, tables, formulas and text”. <https://www.udir.no/kl06/MAT1-04/Hele/Kompetansemaal/competence-aims-after-year-10?lplang=http://data.udir.no/kl06/eng>

In Victoria, Australia, where technology use in pre-university mathematics education has been mandatory since 2009, high-stakes assessments only occur in upper secondary mathematics, where the scores on examinations contribute to a score used for university entrance for many courses. The mathematical methods course incorporates the use of computer algebra system (CAS) technology, which is also required in the examination.

This contrasts with the consistent approach in Germany states where digital tools are mandated in the curriculum, with most schools choosing to use graphics calculators (with and without CAS functionality). The “Abitur” forms the final qualification, which involves a project element that can include the use of (CAS or non-CAS) technology within tasks that have been approved by the German “Institute for Educational Quality Improvement.” The German and Australian experiences have influenced the trajectory of curriculum and assessment in England (Button 2013).

Teacher Preparation and Support for Teaching Mathematics with Technology

There is wide variance in the countries’ policy and practice concerning the preparation of teachers to use technology within mathematics teaching. For example, in Australia, there is an expectation that graduate teachers can use ICT in their teaching (as prescribed in the teaching standards: <https://www.aitsl.edu.au/teach/standard>). The implication is that initial teacher training would prepare pre-service teachers to meet these standards. However, although there is no national

policy about the technologies used in mathematics specifically, taking the standards and curriculum together suggest that pre-service teachers do learn about mathematics specific technologies, as well as general technologies.

In Ireland, where the initial teacher education curriculum is not prescribed at a national level, there is an expectation (rather than a policy) that pre-service teachers will be introduced to appropriate mathematical technology. This picture is replicated in several other countries (i.e., England, Israel, Scotland). A number of countries report compulsory or elective courses within initial teacher education programs that are specifically focused on technology use in mathematics education (France, Portugal, Turkey).

For in-service teachers, again the picture is varied. Few countries report state-funded professional development (PD) initiatives in this respect, with most indicating that it would be the choice of the teacher to focus on mathematical (as opposed to generic) technologies. (i.e., England, France, Germany, Netherlands, Norway, Slovakia). In some cases, the PD opportunity is offered through local or regional networks, resulting in a varied picture of uptake, and therefore impact. Alternatively, government-funded initiatives led by university-based mathematics education teachers/researchers, such as the “m@t.abel” project in Italy (<http://www.scuolavalore.indire.it/superguida/matabel/>), have involved large numbers of teachers in focused PD.

Massive open online courses (MOOCs) are an emerging phenomenon for teacher PD, with colleagues in France, Italy (<http://www.difima.unito.it/mooc/>), and Norway all reporting their development, alongside some early evaluations (Panero et al. 2017; Taranto et al. 2017). A significant international community that has evolved from the GeoGebra software user group has now established formal PD programs in many countries (Italy, Hong Kong).

A number of studies are identifying the design principles for, and impact of, larger-scale PD programs for mathematics teachers, exploring the role of PD “multipliers” (Barzel and Biehler 2017) and online PD models (Clark-Wilson and Hoyles 2017).

Concluding Comments

Very few of the countries reporting for this review indicate any large-scale evaluation of the impacts of classroom use of mathematical technologies on students’ educational outcomes. Where evaluations have occurred, these were mostly smaller-scale studies of particular technology interventions (Wang 2011). Norway and Germany seem most advanced in this respect, conducting annual surveys of technology that reveal patterns of use. However, the most recent German report reveals that current teaching in science, technology, engineering, and mathematics was not bringing about the desired societal impacts relating to high-level technological skills (https://www.telekom-stiftung.de/sites/default/files/files/media/publications/Schule_Digital_2017_Web.pdf).

Regarding the wider use of technology, a large-scale study in Taiwan adapted a set of teacher technology integration performance standards (developed by the International Society of Technology in Education) to evaluate teachers’ technology integration proficiency. This study revealed six scales for teachers’ technology integration, including (1) teaching preparation and information gathering; (2) instructional material and hardware problem-solving; (3) management, communication, and sharing; (4) planning, instruction, and evaluation; and (5) professional development and self-study. Factor analysis revealed that teachers who had experienced more professional development scored higher (Hsu 2010).

As previously mentioned, the societal interest in “big data” is catalyzing curriculum developments with respect to increased use of technology in mathematical tasks that require statistical hypotheses, analyses, and modeling. In England and Ireland, technology is becoming mandated as part of classroom-based tasks and/or high-stakes assessment in this respect.

But a number of key challenges remain. The discussion about digital tools is often driven by the technical aspects of the hardware, rather than the deeper consideration of the (desirable) mathematical affordances to improve students’ engagement and participation in mathematics. This is

reflected in the presentation of curriculum policy guidance that emphasize the students' attributes in terms of their mathematical activity with the technology. Herein lies the biggest challenge. For teachers who have not been inducted into mathematics with technology, significant PD is required to enable them to rethink their own mathematics, alongside the pedagogies that accompany this.

This final comment sums up this issue and highlights the importance that the curriculum and assessment policy developments are underpinned by clear and wide communications of the vision concerning technology use in mathematics – and accompanying professional development opportunities for teachers:

Last summer (2017) Grade 13 students (19-years-of-age) in the scientific high schools were suddenly allowed to use graphical calculators in the National examination of grade 13. This new permission was given in spring 2017, unfortunately without any prior indication or support for teachers. This has caused some stressful situations for these students' teachers because they did not expect such a decision by the Ministry. [Questionnaire respondent]

Cross-References

- [Information Technology and Assessment](#)
- [Restructuring Teachers' Knowledge for Teaching With Technologies With Online Professional Development](#)
- [WhatsApp for Electronic Feedback and Assessment](#)

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Methodological Quality of Educational Technology Meta-analyses

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Introduction

Scientists have known for centuries that a single study will not resolve a major issue. Indeed, a small sample study will not even resolve a minor issue. Thus, the foundation of a science is the culmination of knowledge from the results of many studies. (Hunter et al. 1982, p. 10)

Gene Glass's meta-analytic work in psychotherapy and on class size in education marked the beginning of a new era in systematic reviews (Glass 1976; Glass and Smith 1979). Despite the initial objections of some skeptics (e.g., Eysenck 1978, 1995; Gallo 1978; Presby 1978), meta-analysis (M-A), as a methodology of quantitative synthesis, has continued to grow exponentially and has become the most reliable source of comprehensive summaries of quantitative research in

a wide variety of fields (Glass 2016; Shadish and Lecy 2015).

However, like any other form of research, M-As can be biased in a number of ways (e.g., Abrami et al. 1988; Bernard et al. 2014a; Benard 2014; Cooper 2016; Polanin et al. 2016) and as a result possibly misrepresent the state of a research literature. Thus, attention should be paid to identifying sources of bias in M-As similar to that given to evaluating the quality of primary research (e.g., Valentine and Cooper 2008).

Narrative reviews and vote-counts are insufficient for achieving the degree of precision and comprehensiveness that M-A can. They are neither scientifically sound (Kline 2004) nor adequate in extracting information from the vast body of literature, organizing it, analyzing it, and presenting it (Glass 1976). They do not account for different sample sizes and the varying strength of results in different studies, they are not statistically powerful, and they do not address the size of the effect in a given study (Abrami et al. 1988; Hunt 1997). Furthermore, they rely heavily on statistical test outcomes, namely the p value, which is subject to all the null hypothesis testing limitations emphasized by many researchers including Meehl (1967), Cohen (1990), and Glass (1976). Finally, they are highly subjective (Bernard and Naidu 1990; Slavin 1984) and most of them are restricted to published research studies which includes the overestimation bias entailed with that (Kline 2004). As such, and while both approaches could be used with the methodology of systematic review (Cooper 2010), their limitations at the synthesis stage render them vulnerable to bias and misinterpretation.

Many general descriptions of M-A (e.g., Bernard and Naidu 1990; Card 2012; Cooper 2016; Cooper et al. 2009; Hunt 1997; Hunter and Schmidt 2014; Lipsey and Wilson 2001) address specific aspects of M-A conduct and reporting. Some works focus more on statistical analysis (e.g., Borenstein et al. 2009; Hedges and Olkin 1985; Pigott 2012), while others address specific issues of the methodology, such as acquiring literature (e.g., Hammerström et al. 2010), controlling publication bias (e.g., Polanin et al. 2016; Rothstein et al. 2005), and

addressing sample dependency questions (e.g., Scammacca et al. 2014). Furthermore, a number of associations have been formally established for the purpose of supporting systematic reviews in general and meta-analyses in particular (Bernard et al. 2004). Examples include the What Works Clearing House, the Cochrane Collaboration, and the Campbell Collaboration.

A general Google Scholar search on the 23rd of January 2018 for the term *meta-analysis* with no restrictions returned more than 3,500,000 hits in various fields of study. This is a solid indication that M-A has become a widely accepted approach for research synthesis in a variety of disciplines. A more education-focused search of the ERIC database on the same date resulted in the return of 5912 documents. This is a substantive (more than five times) increase from the 1100 documents that were located through the same ERIC search in 2009 (Tamim 2009). Such a burgeoning literature suggests that, in principle, this approach to research synthesis will only become more ubiquitous.

However, there are often disconnects between the methodological literature (i.e., what should be done) and the methodological practices that populate the research literature (i.e., what is actually being done). It comes down to this: when several M-As disagree, which results should be trusted more, and which should be interpreted with caution, or even rejected outright, because they could be severely biased? This very question is at the heart of this article: can an instrument be developed to reliably evaluate the methodological quality of M-As in the social sciences to reveal their areas of strength and weakness?

Several notable attempts to develop instruments to evaluate methodological quality of M-As come from the health sciences and allied fields (e.g., Higgins et al. 2013, Moher et al. 1999 – QUOROM; Schlosser et al. 2007 – EVIDAAC Systematic Review Scale; Shea et al. 2007 – AMSTAR). All of these instruments use a checklist and rating scale approach and have been tested with various M-As (e.g., AMSTAR was applied to nursing interventions by Seo and Kim in (2012). In the social sciences, however, there has been less activity devoted to developing a methodologically

sound and user-friendly tool that may be employed by producers, reviewers, and consumers of M-As. Below are some previous notable attempts.

1. Abrami et al. (1988) explored implementation problems in M-As by comparing six quantitative reviews from the literature of student ratings of instructional effectiveness;
2. Steiner et al. (1991) produced a methodology checklist for M-A and conducted a review of 35 published M-As in the areas of organizational behavior and human resources;
3. Torgerson (2007) reviewed and assessed the methodological quality of M-As addressing literacy learning in English;
4. Tamim (2009) conducted a second-order M-A of 25 M-As in the literature of educational technology, and as part of the method, evaluated these studies for their methodological quality;
5. Ahn et al. (2012) published a generalized assessment structure developed and used to evaluate M-As that had appeared in the *Review of Educational Research* between 1986 and 2013; and
6. Valentine et al. (2010) examined the quality of M-As in the after-school programs literature using a procedure that they developed.

However, unlike the health sciences, currently no specific and generally accepted approach has been designed and utilized for the evaluation of the methodological quality of M-As in the social sciences. While meta-analysts in the social sciences could make use of some of the tools from the health sciences, there are enough differences in the literatures to warrant a dedicated instrument. Most notably, there is the conceptual difference in the research paradigms in both areas of study with varying implications for practice. Primary research studies in the medical field are generally characterized by the clarity and focus of the research question and their high quality with regards to experimental research design (i.e. randomized control trials), and validity and reliability of outcome measures that are also used more consistently across individual studies. In contrast, primary research studies in social sciences generally address broader questions with limited

applicability of true experimental designs while employing a multitude of assessment tools of varying psychometric quality. Implications of that difference affect various aspects of M-A implementation, among which probably the most important one is selection of a proper analytical model (i.e., fixed versus random) for the effect size aggregation.

The current approach discussed here follows from the work of Tamim (2009) and is an unfolding attempt to design and develop a reliable instrument to evaluate the quality of reports of M-As around social science questions in general and education in particular, including the assessment of potential sources of bias in the different stages of the process. The particular objective is for the instrument to assist researchers, policy makers, journal reviewers, and graduate students in evaluating the methodological quality of M-As in their respective fields of interest.

Bias in Meta-Analysis

Benard (2014) defines bias in M-A as intentional or unintentional systematic inaccuracy in data due to characteristics of the processes employed in its collection, analysis, and interpretation that might affect a consumer's understanding of the review. It is understood and accepted that no methodology is completely immune to bias, and in many cases, especially in M-A, bias emanates from practice, not from conception. Considering that M-As are population studies that intend to evaluate the state of an entire collection of related primary research, the consequences of bias are much more detrimental than in individual primary research studies. Furthermore, this concern is exacerbated by the fact that, from a procedural perspective, a M-A entails a number of judgment calls that might have a considerable impact on its validity (Guzzo et al. 1987; Cooper 2017).

Particularly speaking, bias can reside in any of Cooper's (2017) steps for conducting a M-A, namely: formulating the problem; searching the literature; gathering information from studies; evaluating quality of studies; analyzing and integrating research outcomes; interpreting evidence; and

presenting results. However, the authors stress that not all steps of a M-A are equally vulnerable and argue that the most crucial types of bias are:

1. Publication bias which is related to Cooper's literature search step
2. Out-of-range effect sizes which is related to Cooper's gathering information step
3. Poorly designed primary studies which is related to Cooper's evaluating quality of studies step
4. Choice of the appropriate analytical model and overly leveraged effect sizes (which relates to Cooper's analyzing and integrating research outcomes step)
5. Confounded moderator variables which is related mostly to Cooper's interpreting evidence step

A brief overview of the listed potential sources of bias are given in Table 1. For a detailed overview and means of detecting bias in a M-A and correcting for it, check Bernard et al. (2014a) and Tamim et al. (under review).

Methodological Quality of Meta-Analyses

Considering that M-A was introduced about four decades ago and has since been established as an extremely powerful and valuable methodology for research synthesis, but not a straightforward (quite complex and sophisticated) one, questions about its methodological quality have become more pressing. For example, some researchers have long argued that the effect size offered by M-A may have "mischievous" outcomes especially with novice readers who may take the apparent "objectivity," "precision," and "scientism" as a seal of credibility (Cook and Leviton 1980). In a counter argument, Cooper and Arkin (1981) stress that there is nothing "mischievous" in the method itself, rather it may become so in the hands of some researchers due to "intention" or "ignorance," which is applicable with any innovative methodology. This is only heightened by the fact that many researchers have repeatedly

stressed that the main concern about the quality of meta-analytic findings is not related to the theoretical construct of the M-A, but rather to the quality of implementation by different researchers (e.g., Abrami et al. 1988; Benard 2014; Slavin 1984). The upcoming section describes the design, development, and verification process for a recently-developed approach, the *MMRQG*, as a generic evaluation tool to be used in the social sciences. That being said, the verification process for this development specifically used the educational technology literature for three major reasons, namely:

1. the original objective for the development of the first draft of the *MMRQG*;
2. the team's extensive experience in the field; and
3. the availability of a substantive number of published M-As in the area.

An important caveat to the use of the *MMRQG* instrument is that it applies to publicly available documents that report on various aspects of implementation of the methodology of M-A, not to actual review conduct (unless it is used by a novice researcher to guide the review). Hence, readers/assessors can only rely on what is explicitly reported by the authors of a M-A under consideration.

Development of the Meta-Analysis Methodological Reporting Quality Guide (MMRQG)

The Origin

The impetus for this project emerged from the development of an instrument originally designed by the first study by Tamim (2009), to help judge the quality of M-As that were to be included in a second-order M-A of the literature of technology integration in education. The instrument included 14 different items that addressed the comprehensiveness of a M-A (seven items) and its rigor (seven items). Items addressing comprehensiveness were: (a) literature covered; (b) search strategy; (c) resources used; (d) number of databases

Methodological Quality of Educational Technology Meta-analyses, Table 1 Overview of major sources of bias in M-A

Bias	Overview
Publication bias	According to Rothstein et al. (2005), “publication bias is the term for what occurs whenever the research that appears in the published literature is systematically unrepresentative of the population of completed studies” (p. 1). There is evidence that this bias is more likely due to the choice by journal editors to publish studies that “demonstrate an effect” as contrasted with studies that do not or that demonstrate negative results (Song et al. 2010). When appraising a review, readers should determine whether the authors have made serious attempts to locate and review unpublished studies, including conference proceedings, unpublished theses, dissertations, and other, so-called “grey” literature
Out-of-range effect sizes	The synonymous terms “out-of-range-effect sizes” and “outliers” are obviously relative since what is an overly large effect size in one study can be within range and not an outlier in another study. The effect that outliers have on a M-A depends on several characteristics of the effect size and the overall distribution of effect sizes under consideration. Effect sizes derived from primary studies with unusually large sample sizes, even if the effect sizes are not particularly large, can have a biasing effect on the weighted average, especially under the fixed effect model. Methodologically sound M-As necessarily pay attention to a possibility of bias introduction due to out-of-range effect sizes
Poorly designed primary studies	Methodological quality of primary studies, and the potential biasing effect of not addressing threats to internal, external, construct, and statistical validity, have been discussed extensively (Valentine and Cooper 2008). In conducting a M-A, there are several strategies for dealing with methodological study quality which range from being highly selective in the inclusion criteria to less selectivity coupled with various statistical adjustments (Abrami and Bernard 2012). Each of these methods has pros and cons that make it either more or less effective in controlling for methodological quality of studies included in a M-A; however, addressing this potential source of bias is of high relevance when appraising a M-A
Choice of the appropriate analytical model and overly leveraged effect sizes	Hedges and Olkin (1985) and Borenstein et al. (2009) describe two approaches to the synthesis phase of a M-A based on the purpose of the review and the nature and scope of studies that are likely to populate it. If the goal of the analysis is to find a single fixed weighted average effect size, studies must be judged to be essentially alike in terms of research questions, interventions, samples, settings, measures, etc., and if all studies in the population are available, the fixed effect model of synthesis should be used On the other hand, if studies are judged to be sufficiently different from one another in any or all of the above-mentioned characteristics so that a single weighted average does not seem to apply, the random effects model is more appropriate. Moderator analysis is typically conducted using either the mixed-effect <i>ANOVA</i>-analogue or the “method of moments” approach to meta-regression. Appropriate selection of the analytical model reduces the likelihood of bias in a given M-A
Confounded moderator variables	Confounded moderator variables represent one of the biggest challenges in a M-A. A meta-analyst typically deals with descriptions of moderator variables that may be confounded with each other. This makes the interpretation of the findings more challenging than in primary studies where the researcher has more control over the variables under investigation There is a potentially more serious issue of confounding that results from the inclusion of various research designs (e.g. Lipsey 2003). The most extreme difference in effect size might be observed when weak pre-experimental and higher quality designs are included in the same M-A. Consumers of M-A should address interpretations of findings of such reviews with caution

searched; (e) inclusion/exclusion criteria; (f) quality of included research; and (g) time between the publication date of the latest included study and the publication date of the M-A. Rigor-related items were: (a) article review; (b) effect-size extraction; (c) codebook; (d) study feature extraction; (e) independence of data; (f) standard error calculation; and (g) weighting by number of comparisons.

At that time, 38 M-As of varying quality were identified in the educational technology literature. From these, 25 M-As containing no more than 25% overlap among primary studies that were included in all M-As were admitted to the second-order M-A. That study found a significant weighted average effect size of $\bar{g} = 0.35$, $k = 25$, $p < 0.05$, between the treatment group where technology was present in classrooms versus the control condition where technology was absent. The methodological quality instrument allowed for the classification of included M-As into three categories: low quality ($k = 8$), medium quality ($k = 7$), and high quality ($k = 10$). Moderator variable analysis using the mixed model revealed that the three categories could not be differentiated on the basis of effect size ($p = 0.23$). However, there was an indication of an inversely related trend whereby lower quality M-As produced higher weighted averages ($\bar{g} = 0.42$), medium quality M-As produced lower ones ($\bar{g} = 0.35$), and higher quality M-As yielded the lowest average weighted effect sizes ($\bar{g} = 0.31$). For a more detailed overview about second-order M-A, kindly refer to the article (See ► [“Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-Analyses”](#)) (second chapter by Authors).

Refinement

The findings from the initial application of the tool within the context of the second-order meta-analysis strongly suggested the potential merit of investing rigorous efforts into the issue of methodological quality of a M-A and its adequate assessment. As such, the decision was to move forward with further refinement of the tool. In

addition to the comprehensiveness and rigor items, and in order to address issues pertinent to conceptual clarity, two items were added, namely: (a) clarity of the experimental group definition; and (b) clarity of the control group definition. The 16-item instrument was used for the data analysis and findings reported in the second-order M-A of educational technology literature published in the *Review of Educational Research* (Tamim et al. 2011).

In 2014, the authors developed an advanced form of the instrument and pilot tested it. The number of items was increased to more closely match Cooper's seven steps for conducting a systematic review or M-A. Considering that a clear understanding of each item is needed for the tool to be usable, more elaborate descriptions of the items were devised and included in the new version. At that point, the instrument included 26 items that fell in seven categories, namely: (a) problem statement (6 items); (b) literature search (4 items); (c) procedural aspects of effect size extraction and study feature coding (2 items); (d) quality of studies (5 items); (e) synthesis of effect sizes (3 items); (f) interpretation of evidence (2 items); and (g) presentation of results (4 items). For the purpose of the pilot tests, two expert members of the research team evaluated the M-As in the areas of distance education (Bernard et al. 2014b) and technology integration (Bernard et al. 2014a). Both evaluators had previously been involved in every stage of developing and producing multiple M-As and had published M-As in a variety of venues.

Pilot Testing

The instrument was pilot tested with 15 M-As in the distance education literature, ranging in publication dates from year 2000 to 2014 (Bernard et al. 2014a). Two experienced coders used the instrument items to evaluate the meta-analytical procedure for each of the included M-As. The respective frequencies of positive and negative characteristics (not yet numeric values of rating per item) were used to assess the state of the literature. Findings indicated that methodological difficulties, as presented in Table 2, centered

Methodological Quality of Educational Technology Meta-analyses, Table 2 Study characteristic (seven-step review procedure) ratings across 15 M-As of distance education

Scale items	Problem statement (6 items)	Literature search (4 items)	ESs and study features (2 items)	Quality of studies (5 items)	Synthesizing effect sizes (3 items)	Interpreting evidence (2 items)	Presenting results (4 items)
Positive	15	9	14	9	5	14	13
Negative	0	6	1	6	10	1	2

Methodological Quality of Educational Technology Meta-analyses, Table 3 Study characteristic (six steps) ratings across 13 M-As of technology integration in education

Scale items	Problem statement (6 items)	Literature search (4 items)	ESs and study features (2 items)	Quality of studies (5 items)	Synthesizing effect sizes (3 items)	Interpreting evidence (2 items)	Presenting results (4 items)
Positive	13	10	8	6	9	11	N/A
Negative	0	3	5	7	4	2	N/A

around three major areas: literature search (i.e., publication bias); the quality of included studies (i.e., the inclusion of pre-experimental research); and synthesis of effect sizes (i.e., selecting the wrong/inadequate analytical model).

Based on the first pilot test, it was noted that the items included in the “presentation of results” category were realistically subsumed by or addressed in the other items/categories. As such, a subsequent revision of the instrument was performed resulting in the reduction in number of items to 22, addressing all the previous categories except the “presentation of results.”

The instrument was then subjected to a second pilot test with 13 M-As in the literature of technology integration in higher education ranging from the year 2000 to 2014 (Bernard et al. 2014a). The resulting category frequencies in Table 3 indicate adequate quality of M-A implementation with respect to searching the literature. As for the categories of extracting effect sizes and coding study features, the frequencies reflected the varying methodological quality of the M-As. Finally, and similar to the previous pilot study, potential bias vulnerability was detected with respect to synthesizing effect sizes and the inclusion of questionable-quality primary studies.

The Meta-Analysis Methodological Reporting Quality Guide (MMRQG)

As an outcome of the design, development, and pilot testing process, the final form of the *MMRQG* includes 22 items, as presented in Table 4. The items are coupled with brief descriptions that allow users to score each aspect of a M-A to reflect whether and to what extent it conforms to the rigorous standards of meta-analytical research. For every item, a three-level qualitative characterization (based on the information available in the respective reports) was used as follows: (1) yes (requirements for proper meta-analytical procedures/decisions at this stage are fully met); (2) somewhat (requirements are partly met); and (3) no/not reported (requirements are not met or the corresponding information is missing in the M-A report). Some of the items could apply equally to any form of the systematic reviews, whereas others are unique to M-As, as they relate to various aspects of effect size extraction and aggregation.

Verification of the *MMRQG*

As noted earlier, for verification of the *MMRQG*, the field of technology integration in education

Methodological Quality of Educational Technology Meta-analyses, Table 4 *MMRQG*: Items and descriptions

Items	Description
1	Research Question
2	Contextual positioning of the research problem
3	Time frame
4	Experimental group
5	Control group
6	Outcomes
7	Inclusion criteria
8	Targeted literature
9	Resources used
10	Search strategy
11	Article review
12	Effect size extraction
13	Study feature coding
14	Validity of included studies
15	Independence of data
16	Effect size metrics and extraction procedures
17	Publication bias
18	Treatment of outliers
19	Overall analyses
20	Moderator variable analyses:
21	Reporting results
22	Appropriate interpretation

was mainly selected because many individual M-As in this area have been produced over decades (i.e., enabling an investigation of a larger sample of reviews) and because of the team’s experience with this body of the literature. Available to the team were the initial set of 38 M-As reviewed and synthesized in Tamim et al. (2011) dating to the end of 2008. In addition, search updates (using the same strategy and resources outlined in the original second-order M-A) were performed to locate relevant M-As published since 2008. As a result, twelve M-As were added to the collection through the review and selection process carried out by the first two authors. The same two reviewers then independently assessed a sample of 25 M-As (i.e., 50% of the available data set), including all the most recent ones (i.e., published after 2010). Each question on the *MMRQG*, together encompassing all aspects of methodological quality, was assessed using the numeric values described above that reflected the degree to which the respective aspects of each M-A conformed to the “best practices”. Disagreements were marked, discussed, and resolved. Inter-rater agreement rate for initial independent coding was 93.5% or Cohen’s $\kappa = 0.87$.

In addition to establishing inter-rater reliability between the two main expert coders, two relatively inexperienced coders were asked to participate in coding a sample M-As from the complete collection of 50. These coders were graduate students (team research assistants) who had participated in coding moderator variables in some of the team’s previous studies, but never had been involved in the planning and/or execution of a complete M-A. They were given a general introduction to the *MMRQG* and then independently coded ten randomly selected M-As. They subsequently met to discuss any discrepancies and reached agreement on a single combined code that was compared to

that of the expert reviewers. Table 5 reports the results of this coding exercise with all coding statistics (for either pair of comparisons) being reasonable, despite some differences between novice and expert coders.

Simple arithmetical sums of all codes across 22 *MMRQG* items composed the total index of methodological quality with a theoretical range from 0 (all items coded as ‘No’) to 44 (all items coded ‘Yes’). One could reasonably suggest differential weights of individual items (e.g., based on previously discusses major sources of potential bias), but for the purpose of the validation study the “one point for one item” scoring system was used. The resulting scale appeared to be a reasonable approximation of a continuous variable, and as such, was employed in the subsequent meta-regression analysis as an integer predictor for the magnitude of the respective effect size. Additionally, each individual item was subjected to the moderator variable analyses (ANOVA-analogue) as a categorical variable with three (rather descriptive) levels broadly reflecting Low, Moderate, and High methodological quality of a M-A under review.

In the analyses, effect sizes extracted from the reviewed M-As were used, as they were reported and then converted (when required) to the common metric of Hedges’s g . One effect size representing the r -family was converted from a correlation coefficient into Cohen’s d (Borenstein et al. 2009), and then into Hedges’s g . Because in a M-A the unit of analysis is an individual primary study (or, more precisely, an independent extracted effect size), standard error was estimated based on a number of comparisons reported in each M-A under review as follows:

$$SE_{g^{++}} = \sqrt{\frac{1}{k_E} + \frac{1}{k_C} + \frac{g^2}{2(k_E+k_C)}} \left(1 - \frac{3}{4(k_E+k_C)-9}\right)$$

Note that as each comparison requires an experimental and a control group, the reported

Methodological Quality of Educational Technology Meta-analyses, Table 5 Inter-rater reliabilities for three combinations of 10 randomly selected meta-analyses

Reliability metric	Independent decision: expert coder vs. expert coder	Independent decision: novice coder vs. novice coder	Joint decision: expert coders vs. novice coders
% Agreement	97.73%	89.32%	81.51%
Cohen’s κ	0.95	0.79	0.63

number of cases (k) in the formula above was actually doubled (i.e., $k_E + k_C$, where E and C stand for experimental and control condition respectively and k_E necessarily equals k_C).

In total, 50 M-As were located, reviewed, and analyzed. One outlier was detected and removed because of its extreme effect on the data set ($\bar{g} = 3.84$). This outlier originated in a M-A (Yeşilyurt 2010) that did not use standardized effect sizes (i.e., the mean difference was not divided by a standard deviation). As a result, the final number of M-As in the collection was 49.

Quantitative Synthesis of 49 Meta-Analyses

One of the first steps was to examine the meta-analytic results of the entire collection of reviews, independently of their quality ratings. These are the findings that would derive from a second-order M-A.

Table 6 presents summary statistics related to the final collection: the weighted average effect size ($\bar{g}^+$, the average of averages); the number of effect sizes (K , the number of average effect sizes); the standard error (SE , based on $k_E + k_C$); and the lower and upper limits of the 95th confidence interval, resulting from both random and fixed analytical models.

The overall average effect size is statistically significant ($p < 0.001$) for both models. The unweighted average ($\bar{g}^+$) is slightly higher at 0.397 with a standard deviation of 0.228. The heterogeneity statistics based on the fixed effect model indicate that the collection is homogeneous, with an I^2 -value of 9.09%. Therefore, there are no studies that should be removed or reduced in magnitude. These findings compare favorably to the

results achieved in the initial second-order M-A of 25 M-As (Tamim et al. 2011). However, the funnel plot indicated the potential for publication bias. Duval and Tweedie’s trim and fill routine (Duval and Tweedie 2000) indicates that an additional 14 studies would have to be found on the negative side of the distribution to achieve symmetry. This is not considered a particular problem in this study since it was not trying to represent the population values in the results, but to appraise possible connections between the M-A methodological quality and its respective effect size. Nevertheless, it is an indirect indication that the publication bias of primary research may culminate with published M-As, calling for additional attention to assessment of their methodological quality in order to better inform readers’ decisions of how adequately any given M-A represents the state of its corresponding field of research.

Examining the MMRQG

As noted earlier, each M-A was rated by two expert reviewers on each of the 22 items in the MMRQG. Disagreements were discussed, and a value for each item was established by consensus between the reviewers. Table 7 shows the mean and standard deviation for each item.

Factor Analysis

The first step in investigating the characteristics of the MMRQG was to conduct factor analysis to determine if clusters of items formed a discernable underlying structure. Principal components analysis was conducted and Varimax with Kaiser Normalization was used to rotate the factor matrix. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.714, a modest but adequate

Methodological Quality of Educational Technology Meta-analyses, Table 6 Overall weighted average effect size and heterogeneity statistics

Population estimates	K	$\bar{g}^+$	SE	Lower 95th	Upper 95th
Random model	49	0.366*	0.026	0.316	0.416
Fixed model	49	0.356*	0.023	0.311	0.400
Heterogeneity analysis	$Q_{\text{Total}} = 52.80$ ($df = 48$), $p = 0.29$, $I^2 = 9.09$, $\tau^2 = 0.003$				

* $p < 0.001$

Methodological Quality of Educational Technology Meta-analyses, Table 7 Means and standard deviations of 22 *MMRQG* items

Items	Mean	SD
Research question (Q1)	1.65	0.522
Contextual positioning of the research problem (Q2)	1.37	0.668
Time frame (Q3)	0.90	0.684
Experimental group (Q4)	1.14	0.707
Control group (Q5)	0.53	0.649
Outcomes (Q6)	1.02	0.661
Inclusion criteria (Q7)	1.53	0.504
Targeted literature (Q8)	0.98	0.721
Resources used (Q9)	1.22	0.685
Search strategy (Q10)	0.73	0.670
Article review (Q11)	0.14	0.500
Effect size extraction (Q12)	0.29	0.612
Study feature coding (Q13)	0.88	0.904
Validity of included studies (Q14)	0.59	0.734
Independence of data (Q15)	0.47	0.649
Effect size metrics and extraction procedures (Q16)	1.22	0.715
Publication bias (Q17)	0.43	0.791
Treatment of outliers (Q18)	0.45	0.765
Overall analyses (Q19)	0.96	0.576
Moderator variable analyses (Q20)	0.86	0.645
Reporting results (Q21)	1.10	0.653
Appropriate interpretation (Q22)	1.22	0.621

value of the item by sample size ratio, and Bartlett's Test of Sphericity was significant ($\chi^2 = 597.57$, $df = 231$, $p = 0.000$), indicating the absence of an identity matrix (or the presence of underlying inter-correlations). The results converged in nine iterations. Seven factors with eigenvalues greater than 1.0 were extracted, accounting for 74.8% of the variance (Table 8 shows the results from the first three factors).

Factor 1, with an eigenvalue of 8.20, appears to relate to overall general concerns about the coherence of the analysis, the interpretation, the reporting, and description in the M-As. Factor 2 is a combination of general and technical issues, and Factor 3 has to do with review procedures, outlier identification, and the validity of included studies (e.g., research design). All 22 items were implicated in one or more of the seven factors extracted.

Methodological Quality of Educational Technology Meta-analyses, Table 8 Factor structure (first three factors) of 22 *MMRQG* items

Factors	Factor 1	Factor 2	Factor 3
Eigenvalue	8.20	1.81	1.41
Percentage of variance	37.27	8.21	6.31
Item 19. Overall analyses	0.809		
Item 21. Reporting results	0.799		
Item 20. Moderator variable analyses	0.773		
Item 22. Interpretation of findings	0.594	0.450	
Item 4. Experimental group description	0.557	0.446	
Item 2. Contextual positioning of the research problem		0.806	
Item 6. Outcomes		0.722	
Item 16. Effect size metrics and extraction procedures		0.701	
Item 15. Independence of data		0.544	0.539
Item 11. Article review			0.859
Item 18. Outlier analyses			0.709
Item 17. Publication bias			0.693
Item 14. Validity of included studies			0.489

Factor Score Weighted Multiple Meta-Regression

Weighted multiple meta-regression was used to investigate the relationship between the factor structure described above and the empirical effect sizes derived from each study. To do this, factor scores generated from the factor analysis served as predictors in inverse variance weighted multiple meta-regression (method of moments). The dependent variable was *d*-type effect sizes from each study, transformed into Hedges's *g*. The results produced an *R* (multiple correlation) of 0.53 and an $R^2 = 0.28$, or 28% of variance accounted for in the

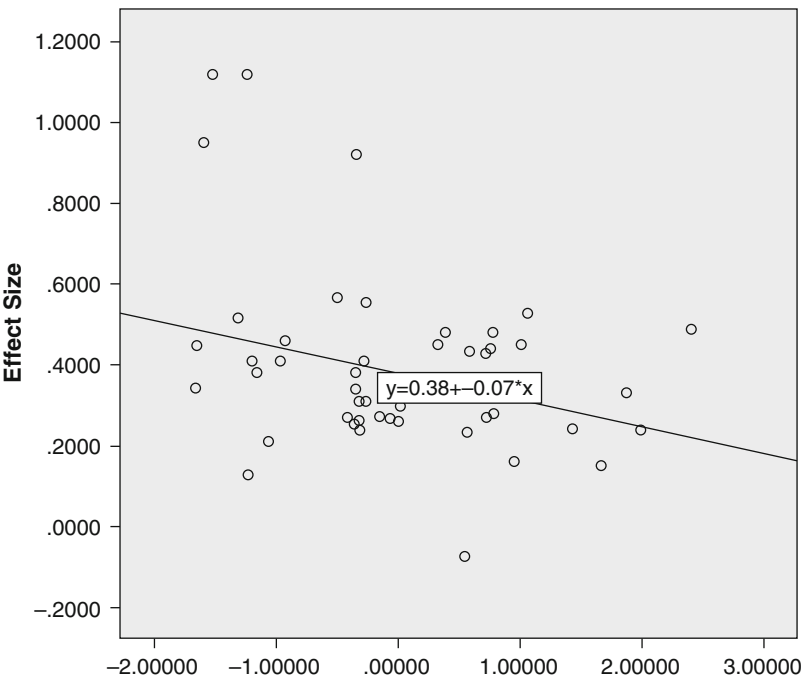
Methodological Quality of Educational Technology Meta-analyses, Table 9 Weighted multiple regression (weighted by factor scores) of seven factors on average effect size with Eigenvalues over 1.0

Factors	β	<i>SE</i>	Beta	<i>t</i> -value	Sig.
(Constant)	0.383	0.025		15.406	0.000
Factor score 1	−0.063	0.024	−0.347	−2.583	0.013
Factor score 2	−0.023	0.027	−0.116	−0.863	0.393
Factor score 3	−0.038	0.021	−0.279	−1.855	0.071 ^a
Factor score 4	0.033	0.023	0.194	1.425	0.162
Factor score 5	0.028	0.023	0.169	1.198	0.238
Factor score 6	−0.008	0.022	−0.056	−0.384	0.703
Factor score 7	−0.002	0.027	−0.008	−0.062	0.951

^aWhile not significant at $\alpha = 0.05$, it is considered close enough to bear further scrutiny

Methodological Quality of Educational Technology Meta-analyses,

Fig. 1 Scatterplot of the regression model of association between MMRQG scores and observed effect sizes



distribution of effect sizes. The *ANOVA* associated with the analysis was significant [$F(7, 41) = 2.28, p = 0.047$], indicating an overall relationship between the independent and dependent variables. Table 9 shows the results of the analysis of each factor. Factor 1 produced a significant relationship between factor scores and effect size and Factor 3 was marginally significant. The slope of the first three factors was negative, indicating that larger effect sizes were related to lower ratings of M-A methodological quality (and the inverse). Figure 1 shows these relationships, graphically.

Individual-Item Weighted Simple Meta-Regression

Of particular interest was the question of whether the methodological quality indicators of the M-As are related to the magnitude of their reported effect sizes. Table 10 shows the results of Factors 1 and 3 regressed on the average effect size with Hedges’s $\bar{g}$ as the outcome variable. Note that, while not significant in multiple meta-regression, Factor 3’s significance level of $p = 0.071$ was considered close enough to bear further scrutiny. Only the significant items within the two factors are

Methodological Quality of Educational Technology Meta-analyses, Table 10 Weighted simple regression of seven items on effect size from two significant factors (as in Table 8)

Items	Point estimate	SE	95th lower limit	95th upper limit	Z-value	p-value
Factor 1						
Item 19. Overall analyses:						
Slope	−0.12	0.04	−0.19	−0.05	−3.35	0.00
Intercept	0.50	0.05	0.40	0.60	10.26	0.00
Item 21. Reporting results:						
Slope	−0.08	0.04	−0.15	−0.01	−2.14	0.03
Intercept	0.46	0.05	0.36	0.56	8.72	0.00
Item 20. Moderator variable analyses:						
Slope	−0.10	0.03	−0.16	−0.04	−3.10	0.00
Intercept	0.47	0.04	0.38	0.55	10.89	0.00
Item 22. Interpretation of findings:						
Slope	−0.08	0.04	−0.15	−0.01	−2.24	0.03
Intercept	0.47	0.06	0.36	0.58	8.42	0.00
Item 4. Experimental group description:						
Slope	−0.09	0.03	−0.15	−0.02	−2.66	0.01
Intercept	0.47	0.05	0.38	0.57	9.49	0.00
Factor 3						
Item 18. Outlier analyses:						
Slope	−0.06	0.02	−0.11	−0.02	−2.58	0.01
Intercept	0.40	0.03	0.34	0.45	14.15	0.00
Item 14. Validity of included studies:						
Slope	−0.05	0.03	−0.11	0.01	−1.68	0.09 ^a
Intercept	0.40	0.03	0.34	0.47	11.96	0.00

^aWhile this item is not significant in regression, it is included here because it is significant in *ANOVA*-analogue moderator analysis (See Table 10)

included in Table 10. Ratings of all seven items were inversely related to effect size, suggesting that higher ratings (i.e., better quality studies for these items) produce lower effect sizes (this finding was also indicated in the analysis of factor scores depicted in Table 9).

As an adjunct to these analyses and to provide a more explicit indication of the magnitude of each quality category, *ANOVA*-analogue mixed effect moderator variable analysis was applied to each item shown in Table 11, with high, moderate, and low forming three methodological quality categories. The advantage of these analyses is that they show the average weighted effect size in each rating category and the approximate difference between effect sizes. Q_{Between} was tested using the Chi Square distribution with $df = p - 1$.

In most cases, lower quality studies (Low or Moderate) tended to produce larger average effect

sizes than higher quality studies, as was indicated in the meta-regression analysis.

Reliability Analysis of the MMRQG

Scale analysis (i.e., Cronbach's α) was conducted on the set of 22 items and subsequent reductions, to determine if the instrument's reliability was affected by the removal of each item in turn. The results for alpha are shown in Table 12 along with the estimated random error variance for each collection. These analyses reveal that the reduction of items, based on factor analysis and meta-regression had minimal effect on the reliability estimates. All of these reliabilities are considered reasonable for a standardized instrument (Tavakol and Dennick 2011).

In order to further investigate the reliability of the *MMRQG*, a split-half analysis of the two major sections of the instrument was performed. Items

Methodological Quality of Educational Technology Meta-analyses, Table 11 ANOVA-analogue moderator variable analysis (mixed model) for each significant *MMRQG* item

Quality levels	K	$\bar{g}^+$	Lower 95th	Upper 95th	Q_{Between}
Factor 1					
Item 19. Overall analyses					
Low	9	0.55	0.32	0.79	
Moderate	33	0.37	0.31	0.43	
High	7	0.27	0.20	0.35	
Between groups, $df = 2$	6.81, $p = 0.03$				
Item 21. Reporting results					
Low	8	0.39	0.25	0.53	
Moderate	28	0.42	0.33	0.50	
High	13	0.29	0.22	0.36	
Between groups, $df = 2$	5.98, $p = 0.050$				
Item 20. Moderator variable analyses					
Low	14	0.45	0.32	0.58	
Moderate	28	0.38	0.32	0.45	
High	7	0.27	0.19	0.34	
Between groups, $df = 2$	7.88, $p = 0.02$				
Item 22. Interpretation of findings:					
Low	5	0.36	0.20	0.52	
Moderate	28	0.44	0.35	0.52	
High	16	0.29	0.22	0.35	
Between groups, $df = 1$	7.42, $p = 0.02$				
Item 4. Experimental group description:					
Low	9	0.47	0.29	0.65	
Moderate	24	0.40	0.32	0.48	
High	16	0.29	0.23	0.36	
Between groups, $df = 2$	6.44, $p = 0.04$				
Factor 3					
Item 18. Outlier analyses					
Low	35	0.40	0.33	0.47	
Moderate	6	0.38	0.20	0.55	
High	8	0.27	0.19	0.35	
Between groups, $df = 1$	6.41, $p = 0.04$				
Item 14. Validity of included studies					
Low	27	0.38	0.31	0.45	
Moderate	15	0.42	0.30	0.54	
High	7	0.27	0.19	0.35	
Between groups, $df = 2$	6.27, $p = 0.04$				

1 through 11 are items that can apply to any systematic review, whereby items 12 through 22 are items that address meta-analysis specifically. Average item values were generated across the 49 M-As and divided into blocks of eleven items each. The Pearson Product-Moment Correlation between the two halves of the instrument was $r = 0.79$,

$p < 0.0001$. The Spearman-Brown correction produced a correlation of $r = 0.88$. This result suggests that there is consistency across the two sections similar to the consistency that was found across the instrument as a whole, in spite of the fact that there is a significant difference between the averages of Section One and Section Two, with Section One

Methodological Quality of Educational Technology Meta-analyses, Table 12 Cronbach’s alpha for the original collection of 22 items and three reductions

Different collections of items	Cronbach’s alpha	Random error variance
Alpha for 22 items (entire instrument)	0.93	0.15
Alpha for 8 significant items (factors 1, 2 & 3)	0.89	0.21
Alpha for 7 items in factors 1 & 3	0.88	0.23
Alpha for 5 items (factor 1 only)	0.87	0.24

being significantly higher than Section Two ($t [48] = 6.09, p < 0.001; M_{1-11} = 1.02, M_{12-22} = 0.77$).

MMRQG and the Date of Study Publication

The final question that we asked was “According to the results of the *MMRQG*, how has the methodological quality of the 49 reviews from this literature changed from the 1980s until the present”? To answer this question, we performed correlational analysis between total score on the *MMRQG* and date of the study. It seems reasonable to suggest that the accumulation of conceptual and methodological literature, since Glass’s first introduction of the methodology in 1983, should have produced a noticeable increase in the quality of M-As. We found this assumption to be partly true in the literature that we reviewed. The correlation between the *MMRQG* ratings and date of publication was $r = 0.48$ ($p < 0.001, r^2 = 23\%$). Figure 2 shows this general increase in methodological quality over time. It might be noted that in the middle period, from about 1995 to about 2010, there are mixed results. However, in recent years there is a more uniformly positive result. When the results indicated above were more closely examined using one-way *ANOVA* with post hoc comparisons, the only significant difference was between the mean of the 1980s category ($\bar{X} = 13.0, K = 3$) and the most recent

period from 2010 to the present ($\bar{X} = 28.75, K = 8$). There is an incremental increase across the other three categories, but these are not significantly different from each other.

While these results are generally positive, it appears that there is still a need to educate aspiring meta-analysts in the best and most up-to-date information on the methodology. In addition, there is still, and likely always will be, a pressing need to teach graduate students how to conduct M-As that are complete, methodologically sound, and to the extent possible, free of bias.

Discussion

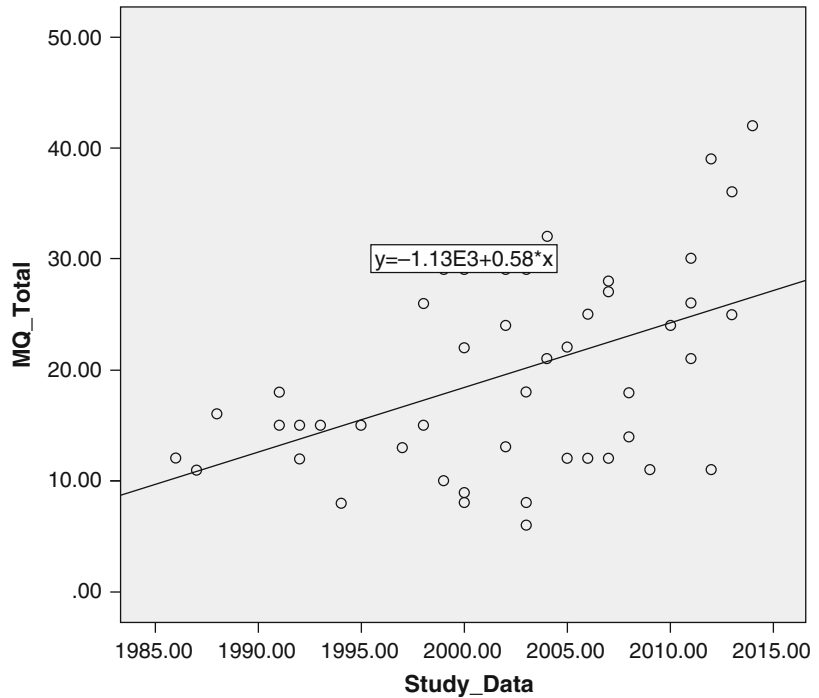
An iterative process, which spanned almost 10 years and included three revisions and two pilot tests, resulted in the production of a 22-item *MMRQG*. While the instrument itself was not the primary objective of the original project (Tamim 2009), the importance and relevance of such a tool to users, journal reviewers, graduate students, and producers of M-As in the social sciences, particularly in education, has become more evident with time and with the ongoing publication of M-As in a host of fields, and often multiple M-As produced around a given topic. As such, the main objective of the current project was to formalize and verify an instrument to eventually make it available to various audiences for the purposes of evaluating the methodological quality of M-As in the social sciences, particularly in education.

The final verification of the instrument involved expert rating of 49 M-As from the literature of educational technology – more specifically, the effects of the application of technology (in comparison with no technology) used in elementary through university education from 1985 through 2014. The results of the verification study of the *MMRQG* allows for several noteworthy conclusions to be drawn.

1. The instrument seems to have a dimensional structure that separates items into coherent clusters, particularly in regard to the highest loading groups of items. Factor 1 addresses overall general aspects relating to the relevance

Methodological Quality of Educational Technology Meta-analyses,

Fig. 2 Scatterplot of study date by *MMRQG* rating



and coherence of the analysis, and the interpretation and reporting in a M-A; Factor 2 relates to a combination of general and technical aspects; and Factor 3 has to do with review procedures, outlier identification, and the validity of included studies. In all, 12 out of the total of 22 items comprise these three factors and account for about 75% of the total item variance.

2. It is likely that low-quality M-As provide an overestimate of the average effect size. There is a strong negative relationship between the five items in Factor 1 and the average effect sizes reported in the 49 M-As. While remaining negative, this relationship is weaker in factors two and three. The negative sign indicates that higher effect sizes are related to lower quality rating on these items, a finding recently reported by Polanin et al. (2016) in regard to the relationship between publication bias and effect sizes of M-As.
3. More nuanced meta-regression and *ANOVA* analogue analysis at the item level significantly differentiated low-quality ratings from high-quality ratings, although this relationship,

particularly for moderate and low, was not always uniform across all items.

4. The scale estimate (Cronbach's α) of the instrument is generally high and does not diminish substantially as the instrument is gradually reduced from the original 22 items to a subset of five items that comprise Factor 1. The split-half reliability estimate of the two halves of the instrument (i.e., items 1–11 and 12–22) suggests that each subset is as reliable as the instrument as a whole. As an additional note, these results were achieved in spite of the minimal ratio of items to studies that would normally adversely affect all of these analyses, from factor analysis to reliability analysis.

In spite of the predictive validity that has been established for a subset of items, both parts of the instrument are considered to be equally important for judging the quality of a systematic review and M-A. In other words, it is considered to be insufficient to use only the items in Factors 1 through 3 to evaluate systematic reviews. The first 11 items address the early stages in conducting a systematic review of any type, while items 12–22

are mostly related to the technical and statistical aspect of quantitatively synthesizing effect sizes, i.e., more specific to M-A. Not surprisingly, it was primarily the second set of items that was significantly related to effect size, in a negative direction. There is no similar metric for assessing the predictive importance of the first 11 items, but it is known that quality ratings of these items are about the same for both halves. It is judged that a systematic review or a M-A that is deficient across either or both domains of items is potentially problematic. While the current findings do not suggest that average effect sizes from lower-quality M-As should be dismissed entirely, they do imply that these studies need to be interpreted more cautiously, especially when there are other higher-quality reviews of the issue that indicate different results.

In this verification, equal weight was given to each item. No a priori weighting was used in the coding, although empirical weights were applied in multiple meta-regression since the predictors of effect size were weighted in factor analysis (i.e., factor scores). While this examination of predictive validity is interesting and useful, it does not tell the whole story about the non-predictive items generally found in the first half of the instrument or their relative value for the purposes of this project. There tends to be a “feed-forward” effect in constructing a M-A. That is, decisions made in the early stages (e.g., establishing inclusion-exclusion criteria) can and do impinge on later stages. For instance, the decision to include only studies from peer-review journals (Item 10) can create bias that may only be detectable in publication bias analysis (Item 17), leading to potentially biased overall analyses (Item 19), reporting (Item 21) and interpretation (Item 22) of the M-A results. So, it would be incorrect to assume that the items in the second half of the instrument are more important than those in the first.

One of the limitations of the *MMRQG* development study is that it was conducted with one body of literature that may or may not be representative of all such collections in other domains. Therefore, other researchers are encouraged to conduct similar exercises for similar collections in other fields of study in the social sciences. Analogous results from other areas might suggest adaptations for special cases,

and future efforts might be able to develop conceptually-based differential weighting of the various *MMRQG* items.

In practical terms, the ratings of the *MMRQG* by two expert and two novice researchers in the evaluation process of 49 M-As addressing the impact of technology integration on student learning supports its applicability, at least, within the field of education. While both experts and novices may use this instrument, it is arguable that it would be most beneficial for mid-level evaluators of M-As, such as graduate students, researchers, and journal article/dissertation reviewers. It is understandable that this target audience may need a guide to the most salient aspects of a systematic review or M-A. Of particular relevance is the fact that, although interrater agreement analyses indicated a difference between novice coders and expert coders, all outcomes were statistically reasonable. This strongly suggests that the *MMRQG* is not out of the novice researcher's reach.

Considering the complexity of the statistical analysis procedures in a M-A, the *MMRQG* in its current form, particularly items 12–22, requires specialized knowledge for a user to derive the most benefit from it. Subsequently, the task of further refinement of the instrument for less informed audiences, especially graduate students, is under consideration.

In Conclusion

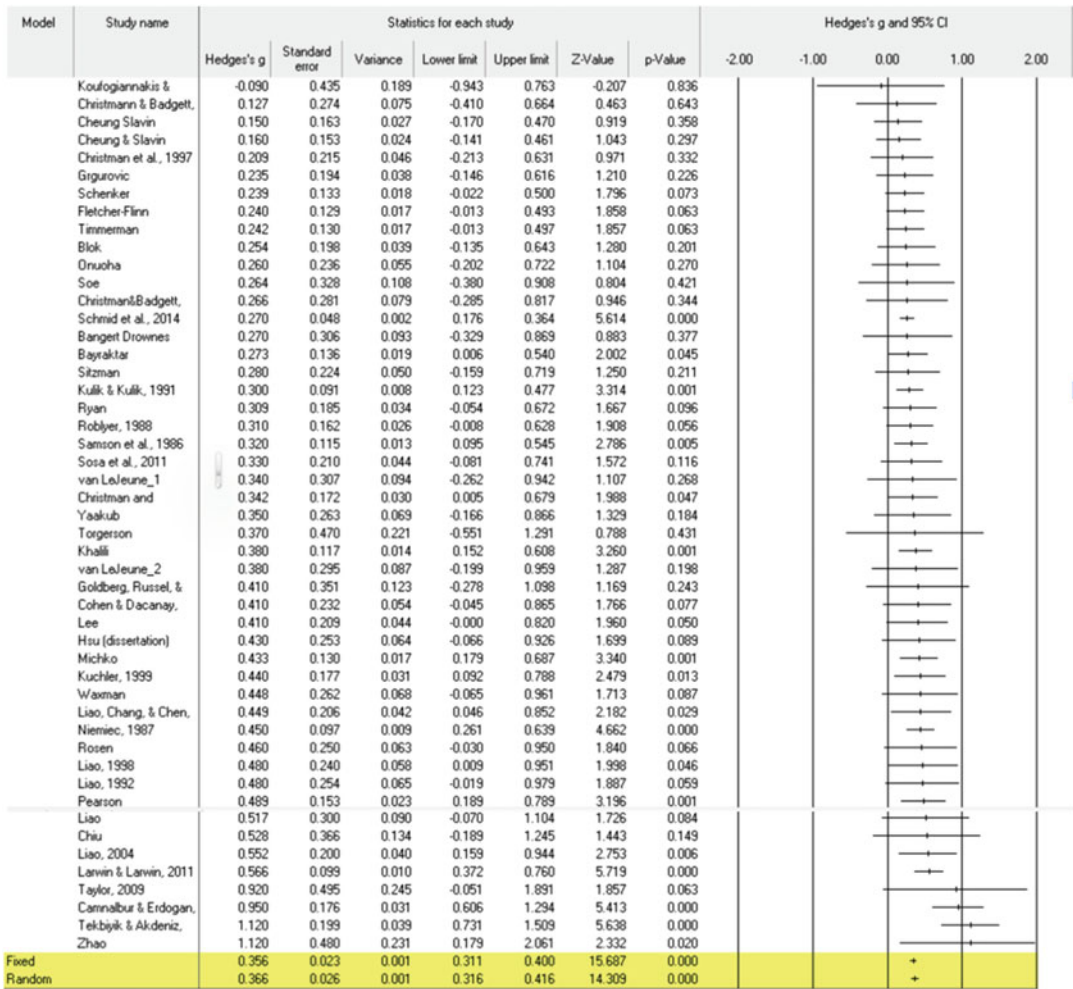
Four decades after its introduction in the 1970s as a quantitative review methodology, M-A has demonstrated its ability to overcome criticism and gain traction among researchers as a systematic approach for synthesizing quantitative research findings (Glass 2016). However, it has to be widely recognized, by producers and consumers alike, that M-As vary significantly in terms of current best practices and processes. The *MMRQG* provides a means of evaluating the quality of M-As that are already in the literature. As well, its structure can be used as a guide to producing new M-As. By far the best way to improve the practice of M-A is through training, experience and understanding, and use of the prolific methodological literature that has developed

since the 1970s. The same might be said about those who intend to evaluate M-As using designed instruments, including the *MMRQG*. The use of the *MMRQG* by meta-analysts, journal reviewers, and consumers of M-As, not only as an assessment tool, but also as a learning tool, is expected from results to date to have a positive impact on the methodological quality of M-As and further substantiate the validity and reliability of findings, as well as increase preparedness of broader audiences of researchers to meaningfully use and confidently produce better quality (i.e., more credible) M-As in the social sciences.

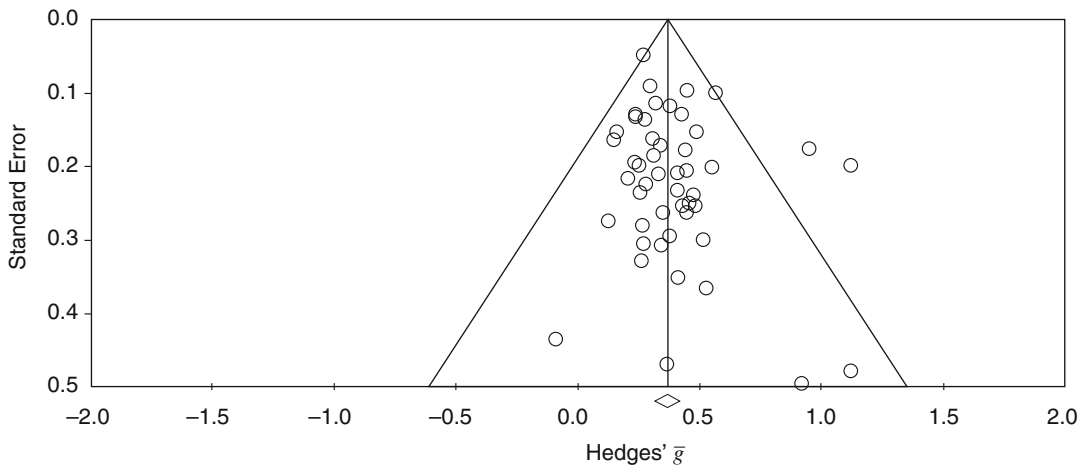
Cross-References

- ▶ [Computer-Assisted Instruction, Changes in Educational Practice as a Result of Adoption of ICT](#)
- ▶ [Computer-Assisted Learning](#)
- ▶ [Computing Education, Outcomes of](#)
- ▶ [Methodological Quality of Educational Technology Meta-analyses](#)
- ▶ [Technology Enhanced Learning](#)

Appendix



Methodological Quality of Educational Technology Meta-analyses, Fig. 3 Study statistics and forest plot of 49 meta-analyses



Methodological Quality of Educational Technology Meta-analyses, Fig. 4 Funnel plot of 49 meta-analyses

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Mobile Computing and Mobile Learning

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Introduction

Mobile computing serves as a learning technology that is ubiquitous in nature, highly portable, and endowed with multimedia capabilities that contribute significantly to a new dimension of learning content delivery to students. The results of numerous research studies that examined the contribution of mobile computing to the teaching and learning processes conclusively confirm that sophisticated digital mobile technology in its different forms serves as a vital and legitimate delivery platform for learning throughout the educational system. The introduction of digital mobile technology into the educational domain has contributed to the enhancement of instruction and learning at all levels of the educational system. Mobile devices add innovative educational features to teaching and learning that make the educational experience more motivating and exciting. These advances have prompted educators to increasingly utilize mobile devices to promote teaching and learning. Mobile devices transform the teacher-student relationship and lead to significantly interactive engagement between teachers and students in the educational process. Mobile computing and learning has changed the face of the traditional classroom and school and has led to an educational framework that is not necessarily bound by time or location but actively connects teachers and students in a digital framework. The sophisticated advancement of computing and communication technologies made over the past years in the parallel development of digital databases and the technological ability to deliver the knowledge stored in these databases through high-speed and reliable

Internet connections have laid the foundations for advanced technology-based learning paradigms that range from electronic learning (e-learning), distance learning (d-learning), and mobile learning (m-learning) to ubiquitous learning (u-learning) (following Katz 2014).

The technological platform that allows for mobile computing and learning is the internet which has become the main vehicle for the dissemination of up-to-date knowledge to all potential learners. Mobile devices connected to the Internet have become part and parcel of the teachers' and learners' daily educational experiences. Being ubiquitous, mobile learning is suitable for learning outside formal school settings and formal school timetables and can be conducted without limitations of time and location. Thus, the ubiquitous nature of mobile learning provides for a rich variety of teaching and learning alternatives that enhance both cognitive and affective domains so vital for significant educational processes. In addition, the growing use of mobile computing and learning in educational settings suggests that the classroom will increasingly be characterized using mobile computing in routine teaching and learning activities. This development will enhance the personalization and customization of learning for the individual learner with the individual teacher's role increasingly becoming one of a facilitator.

Technical Characteristics of Mobile Computing and Learning

Mobile computing and learning, a specific development of internet-based electronic learning, offers a rich and sophisticated technology-based learning environment that is especially characterized by innovation offered to the learner. Additionally, mobile learning has the characteristics of portability, convenience, and interactivity without strict requirements for time, environment, and location, so that students can learn at their leisure. It should be noted that the use of mobile learning provides enhanced technological possibilities of using small and lightweight handheld devices such as iPads, tablets, and smartphones

which include text, voice, still camera, video camera, paging, and geo-positioning capabilities. These tools provide a rich variety of technology-based delivery strategies that enhance student-centered learning. Desktop PC computers are constrained by their static location and are too heavy to be moved easily so that learners are compelled to work in the same place. Even regular laptop computers can be a little cumbersome and uncomfortable to use anytime and anywhere. By contrast, learning with a small handheld device is comfortable with little physical limitations because of size and technological potency. Specifically, flexible portability is the most distinctive feature which distinguishes handheld devices from other emerging technologies, and this factor makes other technologically enhanced attributes such as individuality and interactivity possible. Although tablets and iPads and even small-screen laptops are handheld devices suited to act as receivers of mobile learning, the handheld smartphone is the most prolific mobile learning device available and competently serves as the preferred effective, efficient, comfortable, and user-friendly receiver of mobile learning delivery. In addition, the sophistication of smartphones makes them highly prestigious from the psychosocial point of view and therefore the most preferred and desirable instruments of learning among young learners at school and university age (following Katz 2015a).

Pedagogical Characteristics Related to Mobile Computing and Learning

Mobile learning, which enhances students' learning experiences and offers them almost unlimited access to resources, is an effective platform for the delivery of learning content. Mobile learning contributes significantly towards a more comprehensive educational environment for learning. Learners feel that mobile learning is convenient and easy to use to access databases and knowledge and enhances autonomous learning activity. In addition, mobile computing and learning allows students to engage in problem-solving-based learning activities and to work on tasks

that are goal-oriented and open-ended. In addition, mobile learning empowers students to be actively involved in the learning process, thus allowing for potential improvement in the educational experience (Wang 2017).

Mobile learning particularly provides opportunities to learn through the medium of flexible delivery platforms. Recent studies (following Katz 2015a) have indicated the increasing effectiveness of the contribution of mobile learning delivery platforms to the enhancement of the learning process. These studies have indicated that the latest modes of mobile learning delivery are associated with improved quality of students' learning experiences and have emphasized that mobile learning is significantly more flexible and provides students with especially accessible content and sources. In addition, mobile learning is student-centered and promotes autonomous, creative, flexible, motivated, satisfying, and self-confident learning of students. Thus, learning via mobile delivery platforms is positively received by students and contributes to an enhancement of cognitive as well as affective variables that are vital for the enhancement of student performance in the educational process. In short, mobile learning delivery platforms afford ample and potentially effective opportunities to improve student learning at the school and university level.

Cognitive Variables and Mobile Computing and Learning

A number of research studies have indicated that cognitive performance such as achievement and the development of higher-order thinking skills of students is positively related to the use of mobile learning delivery platforms. As technology has developed, mobile learning is increasingly used in a number of areas of content and subject matter, but outstanding examples of mobile learning as an effective learning delivery platform may be found in the domains of language learning and the exact sciences.

Achievement and Mobile Computing and Learning

Mobile-assisted language learning (MALL) is fast developing as a common as well as legitimate learning delivery platform, and widespread research studies have indicated that mobile delivery of vocabulary has a more significant effect on students' vocabulary learning achievement than traditional instruction based on the use of dictionaries. There is solid research evidence that students who studied idioms via mobile delivery were more enthusiastic about their learning and attained higher scores on an achievement test than their counterparts who studied by traditional teaching methods. The above results are most common among students who studied English language vocabulary via mobile delivery to their smartphones and performed significantly better on English vocabulary achievement tests than students who received their vocabulary lessons by way of traditional face-to-face instruction. Additionally, research evidence has indicated that learning mathematics and the exact sciences via the medium of mobile learning delivery enhanced students' understanding of content matter and positively affected their achievement and learning outcomes (following Ituma 2011; Chandra and Watters 2012)

Higher-Order Thinking Skills and Mobile Computing and Learning

Researchers concur that mobile learning acts as a main support to extend and improve learners' capacities to engage in learner-centered, assessment-centered, and knowledge-centered practices that are the basis for the promotion of higher-order thinking skills. Furthermore, learning with mobile technology has clearly shown that the mobility and connectivity of technological tools enable students to become active participants in analytic thinking and evaluation processes rather than being passive receivers of learning content and information.

Mobile technologies offer a new field to explore in which learning opportunities are extensively distributed and shared, thereby increasing

the students' potential to adopt higher-order thinking strategies. Researchers generally agree that learners' positive attitudes toward the utilization of mobile computing can be a significant factor affecting pedagogical approaches to enhance higher-order thinking. Specific research studies have indicated the efficiency of using mobile computing devices as mediators that scaffold and enhance higher-order thinking skills (following Psycharis 2013).

Thus, increasingly more education-related mobile applications have been developed to promote students' overall learning and thinking processes that contribute to enhanced performance. Many mobile learning applications are designed to develop higher-order thinking as well as teacher-student interaction and inter-student collaboration that have been shown to facilitate as well as support higher-order thinking processes (following Katz 2014).

Affective Variables Related to Mobile Computing and Learning

Over and above the relationship between mobile learning and students' scholastic and academic achievement, research studies have been conducted to examine the relationship between mobile learning and students' affective attitudes that contribute to the enhancement of the learning process. Teacher and learner autonomy, teacher and learner creativity, teacher and learner flexibility, teacher and learner motivation, teacher and learner satisfaction, and teacher and learner self-efficacy (which includes teacher and learner technological self-confidence) are some of the major factors that have been found to be positively related to students' willingness to utilize mobile learning delivery platforms in the instructional and learning processes. Katz (2014) described the association of the above factors with mobile learning delivery platforms and the significance of these affective factors in facilitating student achievement and confirmed the results of the abovementioned studies that indicated that

students who attained higher levels of scholastic achievement and success in their studies held significantly more positive affective attitudes toward the utilization of mobile learning delivery platforms in their learning experiences. The following are descriptions of the major affective variables closely related to the effective utilization of mobile computing in the educational process:

Autonomy and Mobile Computing and Learning

Teacher and learner autonomy are significant factors that contribute to effective use of mobile learning. Results of numerous research studies have pinpointed the advantages of teacher and learner autonomy when utilizing mobile learning delivery platforms and have confirmed the relationship between teacher and learner autonomy and effective utilization of mobile technology in the teaching and learning processes. Some of the studies have suggested that teacher and learner autonomy are, in fact, a suggested prerequisite for efficient use of mobile learning in the educational process. Thus, autonomy characterizing both teachers and students can be considered as an important affective variable that serves as a prerequisite for effective and enhanced teaching and learning with mobile computing and learning (following Katz 2014, 2015b).

Creativity and Mobile Computing and Learning

Creative teachers and students are those who invariably indicate a willingness to try new things and use innovative educational approaches such as the harnessing of technology in general and particularly mobile computing, in the educational process. Teachers' creative use of mobile computing in their instructional practices enhances students' tendencies to be more creative and enthusiastic in their studies and facilitates their ability to acquire the creative skills necessary for success in problem-solving and applying knowledge. Current research studies have contended that the use of creative approaches by teachers affords students the opportunity to more

efficiently utilize mobile learning in the learning process. Thus, creativity exhibited by teachers and students can be considered a major affective variable that contributes to the efficiency of mobile computing and learning (following Hosseini 2014).

Flexibility and Mobile Computing and Learning

Research studies that examined the relationship between affective variables and the willingness of teachers and students to effectively utilize mobile computing in the educational process found that personality flexibility is a defining factor in teachers' and students' ability to more readily benefit from the use of mobile learning delivery platforms inside as well as outside of the classroom. In addition, research results have indicated (a) that teachers' flexibility and belief in innovation are major factors affecting the successful use of mobile-based instruction in their classrooms and (b) that students who demonstrate flexibility in their thinking and learning are highly disposed toward the use of mobile learning delivery platforms (following Katz 2014).

Thus, the flexibility variable is significantly related to teaching and learning via mobile computing applications as well as to the enhancement of students' positive engagement in the learning process.

Motivation and Mobile Computing and Learning

Consistent results of research conducted over the years since technology was introduced into teaching and learning processes on a mass scale have clearly indicated that in schools where sophisticated technology-based instructional packages were introduced into the school curriculum, motivation of teachers as well as of students has been enhanced. The use of mobile learning technology by teachers provides them as well as their students with instructional and learning opportunities that motivate them to better deal with the study material than traditional instructional strategies that do not utilize mobile technology. Both teachers and students involved in instruction and learning via the delivery of mobile educational packages have

shown higher levels of motivation than those who used other teaching and learning strategies. In addition, the teachers and students exposed to instructional strategies based on mobile computing perceived teacher-student readiness to interact in the classroom situation to be more positive and intense than in classrooms where teaching and learning did not include mobile-based strategies (following Katz 2015b).

From the abovementioned research results, it certainly appears that motivation is another centrally valuable affective variable that encourages both teachers and students to utilize mobile computing tools in their teaching and learning to promote efficient and positive cognitive and affective interaction in the educational process.

Satisfaction and Mobile Computing and Learning

One of the key affective variables that positively affects teacher and student performance is the satisfaction of both teachers and students with the introduction of mobile computing into the teaching and learning processes. When teachers and students utilize mobile delivery platforms in teaching and learning, the level of their satisfaction with the educational process increases as does student performance. Research studies that addressed the issue of teacher and learner satisfaction with the use of mobile technology in their teaching and learning found that teachers who utilize mobile learning delivery are more satisfied with their teaching and are better liked and respected by their students who are prepared to invest more in their learning inputs.

Additional research results confirmed that satisfaction with the use of mobile computing in the learning process significantly explains the enhancement of students' learning performance, mainly because the mobile-based learning environment specifically fosters student satisfaction with the learning process. The above evidence emphasizes the importance of satisfaction of both teachers and students in teaching and learning and the significant contribution of the use of mobile computing to satisfaction in the teaching and learning processes (following Mayer et al. 2017).

Teacher Self-Efficacy and Mobile Computing and Learning

Over the years, results of research studies have consistently indicated the importance of the significant relationship between teachers' feelings of technological self-efficacy which include feelings of technological self-confidence and the efficient use of technology in their classroom activity. Recent studies confirmed the existence of a reciprocal relationship between self-efficacy and technological self-confidence of teachers and their use of mobile learning applications. In addition, it has become increasingly clear that technological self-efficacy and self-confidence of teachers in the use of mobile computing and learning tools is a major affective variable significantly aligned with the enhancement of students' learning and achievement (following Varol 2013; Katz 2014).

In sum it may be concluded that self-efficacy that includes technological self-confidence is a key factor motivating teachers to use mobile learning strategies in their classrooms. When teachers perceive themselves to be in command of technology in general and mobile learning in particular, the way is then clear for them to employ mobile learning delivery platform tools for the benefit and enhancement of their students' all-round performance.

Conclusion

Over recent years it is becoming increasingly more apparent that the different mobile learning delivery tools and applications that have been developed for use in the educational process have positively contributed to the enhancement and upgrading of teaching and especially learning. As these mobile learning tools evolved and the learning platforms became more sophisticated, mobile learning has become more teacher-student interactive, student-centered, and student-friendly and has led to the enhancement of cognitive input that in turn promotes increased student achievement, effective learning outcomes, and positive affective attitudes toward the learning process. Mobile learning delivery utilizing the advantages of handheld devices, and especially

smartphones, is steadily becoming a legitimate and valued educational possibility and is rapidly changing the future of schools and learning paradigms.

Technology in general and particularly mobile computing have the potential to bring about a dramatic positive change in teaching and learning. Research over the years has indicated that mobile computing contributes to students' cognitive performance as well as to the enhancement of affective variables such as autonomy, creativity, flexibility, motivation, satisfaction, and self-efficacy (which includes technological self-confidence) that have a special relationship with the enhancement of teaching and student learning and performance. Thus, educational authorities are urged to provide the necessary educational and budgetary resources to develop the mass use of mobile computing in the educational system.

Cross-References

- [Mobile Learning](#)
- [Mobile Learning and Ubiquitous Learning](#)

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Mobile Devices

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Mobile Learning

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- [Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools](#)
- [WalkAbout Framework for Contextual Learning Through Mobile Serious Games](#)

Mobile Learning and Ubiquitous Learning

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Synonyms

[Mlearning](#)

Introduction

The last two decades have witnessed an unprecedented growth of mobile technology. Mobile devices such as cell phones, smartphones,

notebooks, eReaders, portable music and video players (such as the iPod), handheld computers, game consoles, and other devices have permeated many facets of our lives (Kukulska-Hulme and Traxler 2008). However, cell phones are the most used of the above devices since they are multifunctional, and they can serve multiple functions including: making calls; surfing the internet; accessing resources; reading books; connecting with others through social media; taking and viewing pictures and videos; and creating, accessing, sharing, and distributing information (Godwin-Jones 2011). The multimedia functionality and its simpler and user-friendly interface make cell phones easier to be used by people who may not have access to or who may be uncomfortable with using other technologies such as desktop computers.

Cellphones in Education

Within the education setting, the penetration of cell phones has been noticeable. While debates on whether cell phones are a beneficial resource or a destructive distraction rages on, the opportunities presented by cell phones cannot be ignored. In reality, mobile technology continues to offer opportunities for different types of instruction and interaction in a flexible and accessible manner (Hyman et al. 2014). The potential for using cell phones in education is enormous in countries of limited resources where there is: no infrastructure to support Information Communication Technologies (ICT); lack of or limited electricity lines and telephone networks; and inaccessible network configurations. These infrastructural challenges facing many countries in the developing world have led to the rapid growth of wireless infrastructure. Cellphone users in Africa have increased at an annual rate of 65%, twice the global average, and more than 70% of those cell phones have internet access (Rao 2011). The number of people with cell phones in Africa grew from 7.5 million in 1999 to 76.8 million in 2004. As far back as 2005, mobile phones were said to be catapulting Africa into the twenty-first century (LaFraniere 2005). This claim was based on the statistics

available at the time, reflecting that 1 in 11 Africans owned a cellphone. In 2017, the number of mobile broadband connections had risen to close to 420 million, according to the report released by Ovum forecaster data service (Reed 2017). In South Africa alone, 75% of those living below the poverty line owned cell phones (Pyper 2013). In 2016, the ownership of cell phones had surpassed the population of South Africa by about 30 million connections and more than 60% of users were browsing the internet from their cell phones. South Africa ranks fifth in the world for mobile data usage, ahead of the USA, which ranks seventh. Therefore, cell phones are, for network access, most suitable in developing countries because they are affordable and have the ability to connect less privileged people to information.

Mobile Learning

The increased access and use of cell phones offer many possibilities for education because they make teaching and learning available anytime and everywhere (Zawacki-Richter et al. 2007). The integration of mobile technologies and learning is referred to as Mobile Learning (mLearning). A cursory definition of mLearning might limit mLearning to using a device that could be carried around for learning. This definition might be flimsy and overlook other important aspects of mLearning. For example, such a definition might suggest that reading a book while on a bus is part of mLearning (Harris 2001). Perhaps the first thing to acknowledge is that it is difficult to define mLearning, particularly because it has to take into cognizance the mobility of the learner, the technology, as well as learning itself (Brown et al. 2010). For many years, there have been attempts at a common definition of mLearning. As far back as 2007, Traxler used past research to categorize definitions of mLearning, which included the following: mLearning is technology-driven; it is a portable version of e-learning; it constitutes connected learning; it is personalized and situated; and it involves supporting student learning and development even when students are located in remote and rural places. These definitions showed

that there was a need for a definition that would depict the multifaceted nature of mLearning and such a clearer definition would, according to Brown and Mbat (2015), strengthen the concept of mLearning. One definition, which embodies the aspects of mLearning, has been provided by Crompton (2015) who has defined mLearning as “learning across multiple contexts, through social and content interactions, using personal electronic devices” (p. 4). This definition focuses on the learner, learning itself, as well as the device used.

MLearning has the potential to provide immense benefits for education in varied contexts. Ideal technologies for education are those that take into cognizance affordability, accessibility, connectivity, and usability (World Bank 2012). The portability of the device, multiple features in mobile devices, the accessibility of technology, as well as the pedagogical prospects all make mLearning appropriate to meet different teaching and learning needs. Thus, the affordances of cellphone use for learning open up new opportunities for exploring the benefits of these ubiquitous devices as delivery for interventions in teaching and learning (Kukulska-Hulme and Traxler 2005).

Context of mLearning

In the early days of investigating how mobile devices could be used for education, mLearning was defined and described mainly from a technocentric view. This initial view of mLearning did not take into consideration the sociocultural issues that may influence the lecturers’ and learners’ attitudes towards using cell phones as a delivery tool. Many years ago, Traxler (2007) argued that mLearning should be conceptualized from the perspective of learners’ experiences rather than the affordances of the technology tools. This balanced perspective is the one that merges the affordances of mobile devices and its characteristics with sociocultural features of the students’ contexts (Kearney et al. 2012). The starting point in using mobile devices for enhancing and supporting teaching and learning, therefore, is examining the context of learning, because it

plays a major role in any teaching and learning endeavor. According to Cole (2003), context is a set of circumstances that an individual interacts with and which are said to influence an individual in various ways. These individual contexts such as the family, society, political, and historical circumstances tend to influence how a child develops (Cole 2003). In the digital era, these contexts may be expanded to include technology, experiences, beliefs, and values that shape and confirm learning practices (Lave and Wenger 1991). Therefore, it is important that pedagogical principles should be guided by the context in which learning is to take place. This shows that human behavior is located within a social environment that influences an individual in various ways. It is therefore important that the analyses of mobile learning should include cultural-historical activity systems, mediated by tools that both constrain and support the learners and this is strongly mediated by its context rather than the educational content (Sharples et al. 2005).

The most significant attribute of mobile technologies, according to Kukulska-Hulme and Traxler (2005) is their ability to support situated learning. In this context, students are able to explore, share, and interact with each other as they try to learn together. Based on the criteria of interaction, independence, access, and flexibility, it can be concluded that mobile learning holds much promise provided that it is integrated into the mainstream provision of education and training especially in developing countries. In the South African context, most students cannot afford computers with internet subscriptions, and access to electricity is still a struggle for those who live in remote rural areas. Many of those who study through Open Distance Learning (ODL) are working adults who have competing responsibilities between work, family obligations and studying (Fozdar and Kumar 2007; Prinsloo and van Rooyen 2007). Because they do not have time set aside for studying, it is important that lecturers take care when they design study material for these students. This means that curriculum developers and teachers should ensure that accessibility and flexibility are part of any ODL learning

program and delivery mode. In this context, giving students these options is not an after-thought or a luxury, it is a necessity equaled to social justice.

MLearning has been utilized in a variety of contexts to serve a plethora of learning needs (Crescente and Lee 2011; Brown and Mbatia 2015). In an ODL environment where teaching and learning are characterized by physical as well as pedagogical separation between students and lecturers (Moore 1993), cell phones provide a range of possibilities for the delivery of distance education. The use of this ubiquitous device is even more critical in ODL contexts where students are faced with a myriad of challenges that are associated with the distance nature of learning. One major challenge in distance education is interaction. The feasibility of interaction in its varied forms, therefore, is onerous, owing to the physical as well as pedagogic distance between students and their lecturers and among the students themselves. The role that communication and interaction play in the learning process cannot be underestimated in teaching and learning paradigms. Mobile technologies thus provide opportunities for optimizing interaction and communication among distance students.

While the cellphone as a device provides ubiquitous and flexible access to content and interaction, such benefits are accentuated and supplemented with mobile applications (apps). Cellphone apps have transformed cell phones to devices for, among others: information creation, editing and sharing; spaces for educational and recreational content as well social forums for discussions. Social media such as Facebook, WhatsApp, Twitter, and Instagram have been used successfully to provide interactive spaces that have enhanced a sense of community among students. Research has demonstrated how WhatsApp can be used to facilitate learning (Bouhnik and Deshen 2014); how Twitter can be used to support online group journaling (Ferguson et al. 2017); teaching vocabulary through Facebook (Ventura and Martín-Monje 2016); as well as comparisons between a traditional educational platform Moodle and traditional social platform Facebook for

group discussions (DeSchryver et al. 2009). Through these mobile-based social media, distance students are granted opportunities for learner support.

At one of the largest distance education institutions, the University of South Africa (Unisa), cell phones have been used mainly for administrative purposes during applications, registrations, assignments, and examinations, particularly with announcements. For example, students are alerted to changes to assignment submission dates through short messaging systems (SMS). Unisa has also integrated mLearning in the library system where the mobile library resource, m-oasis, allows students to search for resources and request them. Of late, Unisa has embraced mobile assessment by introducing an app for submitting multiple choice question (MCQ) assignments through their cell phones. Over and above cutting down on submission times, the mobile MCQ submission is convenient for the students. With regard to actual teaching and learning, a recent study investigated the use of an existing social app – WhatsApp – and a newly developed app for teaching and learning vocabulary at Unisa (Shandu 2017).

Thus far, cell phones have been used for administrative and social support, while recently there is a move to provide cognitive support where students are encouraged to solve problems as they learn. All these interactions have been facilitated and augmented by mobile learning technologies because they are flexible, available, and cater for a myriad of interaction activities (Traxler 2009). The versatility of cell phones is highlighted by Sarraf et al. (2016) who have argued, “Learners can access the required information irrespective of time and location” (2016: 102). What is important is that students interact not only with each other or with their lecturers, but the cellphone itself provides interaction with the content through interaction with the device. It is, therefore, important to reiterate that interaction is not limited to human-human interaction because human-device interaction is also viable and beneficial to facilitate learning. Through the integration of technology in distance learning, quality education has been made accessible at very low cost to a large number

of people who are engaged in other activities of daily living that are likely to bar them from attending schooling on a regular basis (Bollag and Overland 2001).

Pedagogy of Mobile Learning

In trying to understand how mobile technology can be appropriated for teaching and learning at a distance, it is imperative to start by looking at how different mobile learning is from other technologies that are used in teaching and learning (Laurillard 2007). The strength of using mobile technologies is that they offer learning that is intimate, spontaneous, pervasive, and versatile. Mobile learning “provides an enhanced cognitive environment in which distance learners can interact with their instructors, their course materials, their physical and the virtual environment” (Koole 2009: 38). The delivery of content in distance education has to be accessible to students wherever they are and they can study anywhere they want. Therefore, the delivery mode for learning has to be flexible without being tethered to a particular spot or otherwise that would constrain access. It is in this regard that distance education researchers and practitioners continually explore various strategies for enhancing teaching and learning at a distance. One such strategy is to use mobile learning where practitioners take advantage of the ubiquity and wide ownership of mobile telephones for student support. The advanced technological enhancement as well as the range of possibilities for using cell phones for teaching and learning provides opportunity for authentic learning where students participate in the actual work related to their studies.

Kearney et al. (2012) identified three constructs that characterize the pedagogy of mLearning and these include collaboration, authenticity, and personalization. Collaboration enables students to make rich connections with each other. Mobile devices offer a high degree of networking among students. The devices give students an opportunity to learn together through sharing information, developing content, and

solving problems. The idea is to use social networks that students are familiar with to develop socially interactive learning environments as they consume, produce, and share a wide array of information and artifacts across time and place (Kearney et al. 2012). When students are in control of their learning, they are able to link up with other students in collaborative learning networks. Through peer collaboration, according to Laurillard (2007), students are more likely to be motivated to share their work with each other as well as to augment their conceptual understanding with others. In the distance education context, social interaction relates to the socio-emotional aspect of group forming and group dynamics (Kreijns et al. 2003). Mobile learning facilitates this process through building communities of learners who are committed to working together to achieve a goal. “Collaborative learning leads to deeper level learning, critical thinking, shared understanding and long term retention of the learned material” (Kreijns et al. 2003: 336) as well as developing communication and social skills.

While collaboration offers networking space for distance students, the authenticity construct highlights the opportunity for situated learning, while personalization has strong implications for ownership, agency, and autonomous learning (Kearney et al. 2012). When students have control over the physical or virtual learning spaces, the pace at which learning takes place and the time they learn, they tend to enjoy autonomy and are able to create a personalized, tailored learning journey (Kearney et al. 2012). Through multimedia capabilities, mLearning caters for innovative ways to teach such as using augmented reality (Johnson et al. 2009; Cook 2010) which refers to applications where digital objects are related to physical objects (Specht et al. 2011).

Uses and Benefits of mLearning

In addition to providing a space for collaborative learning, mLearning can be used to deliver

content, to facilitate assessment, and to deliver administrative information. Content delivery is another use for mobile learning, although Thornton and Houser (2001) caution that content in mLearning should be delivered in bite-size chunks for convenience. Reading long and bulky documents on a small screen can be tedious, at the very least. However, mLearning does not provide bits of content, but rather “small components, activities or events within any mode of delivery” (Brown and Mbat 2015: 118). Closely linked to content is the use of mLearning for assessment purposes. Mobile telephones, from a very basic model to the more sophisticated smartphones, have been successfully used for assessment such as for university entrance examinations (Laborda et al. 2011). The most basic cellphone can use short message services (SMS) and unstructured supplementary service data (USSD) where questions such as multiple choice questions (MCQs) are answered by sending the corresponding option as a response to questions. These methods do not require internet connections. The more sophisticated smartphones can use more interactive applications and quick response (QR) codes for quizzes to help students move forward through their materials. Mobile assignment submission apps are also used for submitting multiple choice question (MCQ) assignments.

mLearning can be used for administrative purposes by sending notices, announcements, and reminders and is also used for application and registration purposes. At Unisa, for example, when students apply for study at the university, they receive an SMS acknowledging the receipt of application, and they get regular updates regarding their application process. When a student's application has been approved, the student receives an SMS with a link that the student can click to “accept” the offer to study at Unisa. Libraries are also utilizing a mobile version of the catalogue system, which enables distance students to search the library catalogue; requesting materials and contacting subject librarians is convenient and fast. In the past, all these activities were done in person or by sending letters to

distance students via snail mail. These means were not only expensive but were also time-consuming.

The current developments in mobile telephone technologies have seen the rise of mobile apps being used for language learning (Godwin-Jones 2011). While in the beginning, mobile learning leant on SMSes such as that shown in the study by Thornton and Houser (2001), there is currently a myriad of interactive apps specifically for language learning. One such app-based study was conducted by Butgereit and Botha (2009) who used a mobile-based language learning application called Hadedu to encourage high school students to practice spelling or memorize vocabulary through mobile telephones. The vocabulary app was a collaborative effort between teachers and parents who selected the vocabulary to be learned and loaded vocabulary onto a web-based program which, in turn, converted the vocabulary from text to speech and was sent to the learners' mobile telephones as vocabulary exercises. On the web interface, users had a choice of language between English, Afrikaans, Swahili, French, and German and the selected language would correlate with the sound file created for the pronunciation of vocabulary. While there are many apps specifically for vocabulary learning (Siskin 2009), researchers and practitioners have started to explore how social media apps can be appropriated for learning.

New apps, such as WhatsApp, cater for messages in voice, images, video, and typing formats with no limit on the number of characters one can type. One can also send emojis as a nonverbal means of communicating their feelings; users are also able to create groups for interaction. In Barhoumi's (2015) study, it was found that an experimental group that received an extra hour of course discussions on WhatsApp outperformed the control group in the achievement test results. The experimental group displayed more positive attitudes towards learning and the course than the control group. Although it could be argued that the experimental group's performance and attitude gains were based on the extra attention they received (3 h compared to 2 h), the study, nonetheless, shows a

positive uptake of mobile learning where apps, including those that had been traditionally for social media purposes, are now being explored for learning purposes.

In another study, WhatsApp was used to facilitate communication among more mature students. The findings revealed that WhatsApp facilitated the creation of bonds and relationships among the participants (Gachago et al. 2015). The researchers concluded that "the accessibility and immediacy of WhatsApp as a mobile technology using learners' mobile phones, helps in facilitating the coordination of learning, blurring physical and geographical boundaries" (Gachago et al. 2015: 184). A study on the pedagogical suitability of using MXit – a cellphone instant messaging software application developed in Stellenbosch, South Africa – revealed that the social network provided users with a relaxed environment that they owned where they socialized and exchanged ideas in a language with which they felt comfortable (Makoe 2010).

Keegan (2005: 14) argued, "It is not technologies with inherent pedagogical qualities that are successful in distance education, but technologies that are generally available to citizens." Availability is the underlying and foregrounding principle driving mLearning to be considered as more beneficial over other modes of learning. According to Duman et al. (2014), the benefits of using cell phones for learning mainly include accessible content, available support, as well as facilitation of much-needed interaction.

Other benefits of mobile telephones are related to the convenience of the devices themselves in that cell phones are less expensive than computers and laptops (Chinnery 2006). These devices are cheaper to charge, so where electricity is scarce, students can keep their cell phones operating. The portability of mobile devices is another benefit that Traxler and Kukulska-Hulme (2005: 5) point out; mLearning devices are lightweight and handheld, while the sophistication of newer mobile devices is enticing. Because of the endless possibilities of multimedia one can access using mobile devices (Brown et al. 2011: 144–158), mLearning has been used for graphic audio-visual

ways to complement learning (Huang and Huang 2010). Voice recordings also allow learners to replay content as often as they wish. An advantage of this is that the learner carries this learning environment around with him or herself wherever he or she goes, learning anywhere, anytime and at their own pace.

Challenges of mLearning

Despite the documented benefits, mobile learning has not been embraced as much as it could in many developing countries. The reasons for the lack of uptake range from those that are human related – such as students’ and lecturers’ lack of familiarity and readiness – to those that are technology related – such as familiarity and maintenance of devices and apps. Many of the struggles to operate in the digital era are due to lack of the necessary skills to teach stakeholders how to use the devices. In addition to lack of skills, cell phones are primarily used for noneducational purposes such as keeping in touch with friends and family; having to use the same device for learning is a challenging shift for many. Lines become blurred, therefore, between learning through the cellphone and the distractions of social media (Gikas and Grant 2013).

A further challenge to mLearning relates to the financial implications of owning a cellphone. The reality is that students are sometimes not able to purchase their own mobile telephones or the data and airtime needed to keep them connected to the network. Sometimes students resort to using cell phones owned by family members and this makes learning difficult (Kajumbula 2006). In this case, the ubiquity and all the benefits of mLearning would be dependent on the cellphone’s availability. In developing countries, such as South Africa, sometimes the cellphone can be available, but its functionality limited by exorbitant service and data charges. While universities, such as Unisa, have taken strides in making wireless internet available at campuses, distance learning students still need to pay for data charges.

In the past, the challenges related to mobile devices used to refer mainly to the size of the

cellphone screen, which tended to be too small for effective interaction with bulky materials. In mitigating screen size concerns, mLearning emphasized that materials had to be delivered in short concise chunks (Thornton and Houser 2002: 236). Closely linked to screen size, there used to be issues of limited audio-visual quality related to the features of cellphone and data size including “one finger data entry which may be time-consuming” (Chinnery 2006: 13). While these concerns used to be valid challenges to mLearning, it should be noted that mobile devices are improving frequently in terms of functionality and user interface. A decade ago, Chinnery (2006) posited that mobile devices had limited nonverbal communication and limited message length. However, modern day cell phones have improved with bigger screens, clearer image resolution, as well as increased memory for more activities, and they also have apps such as WhatsApp that allow for longer texts and also cater for images, audio, and video content.

Perhaps the most immediate and pressing challenges regarding mLearning are the issues of security and privacy. Security pertains to the device as well as the information contained in the device. In a study conducted in Ghana (Tagoe and Abakah 2014), one of the challenges expressed by participants was the theft of devices, which meant the loss not only of the device but also of the materials therein. Apart from the device concerns, there is a more inconspicuous yet more destructive danger of unauthorized access (Little 2013) to information within cell phones through malware and other hacking mechanisms. MLearning programs are under pressure to achieve data confidentiality and integrity (Sarrab et al. 2016) to ensure that students’ information such as personal details and results are protected. Whether from device or information concerns, Kambourakis (2013) found that security misgivings “can hamper the penetration of mobile technologies into the education realm, and hence prevent stakeholders from capitalizing on the benefits that these technologies bring along” (2013: 68). While these security concerns are valid, it might be that education on safety and security can be a proactive line of defense prior to initiation of mobile-based interventions.

Conclusion

The cellphone has evolved from being a device for calls and messages into a palm-sized computer with multiple functions. With mobile apps, cell phones have been transformed into multimedia devices, which are part of everyday lives. While cell phones have been appropriated for learning through mLearning, the opportunities for interaction and student support have been more marked for distance education, particularly in developing countries. It is acknowledged that technological and human-related challenges still exist, yet the benefits of multifunctionality, accessibility, and availability related to mLearning are substantial.

Cross-References

- [Collaboration and Social Networking](#)
- [Distance Learning](#)
- [Flexible and Distance Learning](#)
- [Mobile Computing and Mobile Learning](#)
- [Technology Enhanced Learning](#)

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Mobile Learning, Challenges in

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Synonyms

Connected learning; e-learning; m-learning;
Seamless learning; Technology-enhanced learning

Introduction

Mobile learning or m-learning, derived from e-learning (Ozuorun and Tabak 2012), and being a subfield of technology-enhanced learning, has

become a prominent research field in the last decade. We have now amassed a wealth of case studies investigating different aspects of the design and implementation of mobile learning environments, as well as a number of reviews synthesizing mobile learning outcomes (e.g., Bano et al. 2018; Crompton et al. 2018; Fu and Hwang 2018; Ibáñez and Delgado-Kloos 2018). While unsurprisingly mixed findings have been reported in the literature (Zydney and Warner 2016), there is strong evidence to show that mobile learning has the potential to facilitate and enhance collaboration, learner agency, and creativity, which are essential competencies of the twenty-first century (Pargman et al. 2018). It has also been highlighted in the literature that mobile learning can be motivational and engaging. The recent US Speak-Up survey (2017) reported that three-quarter of its 36,860 responding teachers felt that the leading benefit of using mobile devices in the classroom was an increase of student engagement (other benefits include preparing students for college/work, increasing access to online content, personalized learning, and facilitating collaboration). This finding is encouraging, since we know that the lack of interest in schooling has become a major issue in the twenty-first century. For example, it has been reported in Iceland that 55% of its upper secondary students do not complete their 4-year program due to the lack of motivation (Kjartansdóttir and Jakobsdóttir 2016).

The prevalence of smartphones and tablets and recent advent of augmented reality, virtual reality systems, and wearable technologies have the potential to generate new learning opportunities, both in- and out-of-school. However, while technology enthusiasts advocate the increasing use of advanced mobile technologies to support and enhance learning across contexts, researchers, practitioners, and policy makers are reminded that there are many challenges in researching and implementing mobile learning environments in formal and informal settings (Lewin et al. 2018). The purpose of this chapter is to interrogate the literature of this emerging field to identify and highlight these challenges and suggest possible pathways for researchers, practitioners, and policy

makers to move forward. In the following section, we will first discuss the changing conceptions of mobile learning to provide a context to better understand these challenges. Then we will discuss some the pedagogical, research, and policy challenges that we currently face.

Mobile Learning Contexts

While there is little disagreement on the unique characteristics of mobile devices, such as “individuality, connectivity, context sensitivity, mobility and immediacy” (Song et al. 2012, p. 680), there is yet no consensus as to how mobile learning should be conceptualized. We note that there has been an evolution of understanding of mobile learning in the last two decades. Earlier definitions of mobile learning were primarily techno-centric in nature (Pachler et al. 2010), focusing on the design and use of mobile technologies to enhance formal learning, and mobile learning was often considered a subset of e-learning (Winters 2006). In the last decade, however, mobile learning research has shifted to focusing on the mobility of the learner and context (Kukulska-Hulme et al. 2011). Increasingly there is a recognition that mobile learning design is not primarily about the technology, and using mobile technologies in the classroom, e.g., providing iPads to students with pre-loaded course content, does not necessarily foster mobile learning (Philip 2017). There has also been a shift away from viewing mobile learning as using technologies to enhance access to information or content. As pointed out by Pachler et al. (2010), mobile learning “is not about delivering content to mobile devices but, instead, about the processes of coming to know and being able to operate successfully in, and across, new and ever changing contexts and learning spaces,” and therefore, it is “not primarily about technology” (p. 6).

Current research on mobile learning highlights the importance of context, emphasizing the varying learning experiences that students can acquire and develop in and across contexts (Sharples 2015a). For example, Crompton (2013) considers mobile learning as “learning across multiple

contexts, through social and content interactions, using personal electronic devices” (p. 4), and Sharples et al. (2007) characterize mobile learning as “the private and public processes of coming to know through exploration and conversation across multiple contexts, amongst people and interactive technologies” (p. 255). Increasingly it has been recognized that learning can take place in physical and virtual sites, as well as in- and out-of-school spaces and contexts, and the emphasis is on “boundary- and context-crossing” (Pachler et al. 2010). Other than the spatial context, the temporal context of mobile learning is also considered important by many scholars. As Norris and Soloway (2018) contend, “mobile *learning* is about support for 24/7, *all the time, everywhere* learning” (p. 860, italics in the original). There are other contextual aspects that are also considered pertinent in mobile learning. For example, Kukulska-Hulme et al. (2011) have highlighted five contextual aspects of mobile learning that we need to consider when designing mobile learning environments, that is, the physical context (physical space), conceptual context (conceptual space), social context (social space), technological context (technologies used), and temporal context (learning over time). Sharples (2015a) argues that it is important to understand the interrelationship between “learning through context,” “learning in context,” and “learning about context” when designing mobile learning environments.

Investigations have been conducted to explore the impact of the physical space or physical environment on mobile learning, and Bligh and Crook (2017) remind us that different spaces have different effects on learning and the learning space of mobile learning should be different from structured formal learning. Recently attention has been focused on how flexible learning spaces are designed so that different forms of learning (individual/collaborative, formal/informal) can be accommodated and connected within the same physical and social environment. These so-called innovative learning environments (ILE) are well supported by networking technologies with high-speed connectivity to facilitate social and informal learning (Bligh and Crook 2017). They are learning spaces created in a formal setting where the

learner is located but virtual presence is simultaneously afforded and mobility across virtual spaces effectively facilitated (Leander et al. 2010).

Erstad (2012) points out that for young people, learning can be a “constant flow of activities” (p. 26), which happens within and across contexts involving online and offline activities. As such, mobile learning research needs to shift its focus from studying a static learning environment to learning trajectories (Leander et al. 2010) in order to recognize learning undertaken in both in- and out-of-school settings. It is noted by Cross (2006) that formal learning has long been overvalued and privileged over other forms of learning, even though people only spend about 10–15 per cent of their total lifetime learning in formal settings. With increasing attention to the importance of lifelong learning in the twenty-first century, how we can bridge formal and informal learning has become a key educational issue (Lewin et al. 2018).

Why is it important to connect learning across contexts? After conducting a review of the literature, Rajala et al. (2016) come up with three pedagogical rationales to justify why formal and informal learning should be connected. The first rationale is to promote educational equity and inclusiveness. They point out that out-of-school knowledge held by underprivileged students is often undervalued and there is a mismatch between knowledge acquired from in-school and out-of-school settings. There is thus a need to address this inequity issue and to legitimize out-of-school knowledge. The second rationale for connecting formal and informal learning is the need to respond to the requirements of the twenty-first century. Rajala et al.’s (2016) review shows that “everyday reasoning and cultural practices” (p. 22) can contribute to a better understanding of school subjects such as science, music, language, math, and sports. A seamless connection can help students develop creativity, active citizenship, and self-directed learning skills. The third rationale acknowledges the importance of the learner’s learning ecology (Barron 2006) which includes a diversity of learning contexts and spaces in supporting development of learner agency and identity.

The term seamless learning is gaining popularity. Recognizing the important link between contexts, Chan et al. (2006) use the term seamless learning to describe continuous learning across different environments supported by mobile devices. In seamless learning students:

can learn whenever they are curious in a variety of scenarios and that they can switch from one scenario to another easily and quickly using the personal device as a mediator...exploration and investigation in the seamless learning space provides a potential to extend formal learning time...into informal learning time, to embrace opportunities for out-of-school learning. (p. 6)

According to Milrad et al. (2013), seamless learning is characterized by seamless adaptivity and connectivity. Seamless adaptivity refers to the use of mobile technologies to provide context-aware contents or services to the learner. Educational augmented reality applications are examples of how context-aware content can be seamlessly provided to the learner. Seamless connectivity means using mobile technologies to enable the learners to continue their learning across devices and settings disregard where they are located.

Researchers also use the learning lives approach (Erstad et al. 2016) or connected learning model (Ito et al. 2013); Kumpulainen and Sefton-Green (2014) to conceptualize boundary crossing between different learning sites and practices. Ito et al. (2013) explain the concept of connected learning:

Connected learning is realized when a young person is able to pursue a personal interest or passion with the support of friends and caring adults, and is in turn able to link this learning and interest to academic achievement, career success or civic engagement. This model is based on evidence that the most resilient, adaptive and effective learning involves individual interest as well as social support to overcome adversity and provide recognition. (p. 4)

Based on the learning lives or connected learning approach, learning activities are designed to cut across boundaries which allow students to make connections of what they learn in different contexts. This design approach is similar to what Mikkola and Kumpulainen (2016) called hybrid learning, aiming to engage students in learning

activities designed to bridge academic and everyday knowledge. In hybrid learning, students are encouraged to use the “material, sociocultural, linguistic, and cognitive resources embedded in their lifeworlds” (p. 173) to enrich academic activities. They gave an example of a yearlong musical production where 11–12-year-old students were asked to write musical scripts in groups. Students were given a personal netbook with collaborative writing and online chat tools to work both in and after school. With the support of mobile devices, the students worked collaboratively across time and space, and they considered their work undertaken in multiple sociocultural contexts as equally valued. Mikkola and Kumpulainen’s (2016) study highlights the importance of transforming the pedagogical culture of the school to support students to engage in holistic learning in both in- and out-of-school contexts.

With the recent advent of augmented reality (AR) applications, mobile learning has taken a step forward in situating learning in the real world and in real time. Being recognized as one of the most promising learning technologies in recent years, augmented reality (AR) systems utilize 3-D technologies and location-aware applications to provide the learners with additional contextual information which is displayed on a head-mounted or handheld device when they interact with real-world objects (Ibáñez and Delgado-Kloos 2018). Learning in real-world contexts with AR systems may therefore increase content understanding (Hwang et al. 2013). As a form of inquiry-based learning, this mixing of the physical and virtual worlds may support the learner to conduct deeper and more creative investigations. AR systems have provided a new way for the learner to access information and content. Instead of using the mouse or keyboard, AR applications now allow the learners to use their bodies to interact with content, thus providing a different educational perspective and experience to understand content (Radu 2014).

Radu’s (2014) review shows that AR applications have the potential to improve understanding

of spatial structure and functioning, physical task performance, and collaboration. These applications may also enhance language associations, improve longer-term memory retention, and increase content understanding and motivation. Findings from the AR Heritage Trails project in Singapore or the AR Trails of Integrity and Ethics in Hong Kong show that the use of AR can help break down the classroom walls to situate learning in the real world (Pegrum 2016). After reviewing 28 AR projects on STEM (science, technology, engineering, and mathematics) subjects, Ibáñez and Delgado-Kloos (2018) categorize three kinds of AR applications, namely, exploration, simulation, and game-based applications. Their review shows that a range of instructional strategies have been used in these applications, including both behaviorist strategies used to support content delivery and constructivist strategies such as simulations, and a few projects used collaborative learning strategies. Ibáñez and Delgado-Kloos (2018) conclude from their review that while these studies had provided some ideas of the affordances and barriers of AR applications, few of them discussed how learning actually took place within the AR environment. In a similar vein, Akçayır et al. (2016) point out that there are some pedagogical and usability barriers in AR applications such as teachers lacking understanding and experience of how to integrate AR into the school curriculum, and the AR systems (sometimes with rather bulky hardware) may be difficult to manage in a busy classroom. In addition to augmented reality applications, recent advent of wearable digital devices such as Google Glass that “incorporate wireless connectivity for the purposes of seamlessly accessing, interacting with and exchanging contextually relevant information” (Bower and Sturman 2015, p. 344) may create new learning opportunities. However, as pointed out by Bower and Sturman (2015), while pedagogical uses of wearable technologies have been suggested in the literature, so far limited empirical research has been conducted to show how they can actually be used to support teaching and learning in the classroom.

What Are the Challenges?

While there is high hope that mobile technology may transform education, there is some concern that this is just another wave of technology that might end up with limited use and impact, as what Cuban (1986) has insightfully predicted over 30 years ago on technology use in education. There is a concern that mobile learning may become just another fad of technology-enhanced learning (TEL), focusing only on the technology itself but not pedagogical integration (Maddux and Cummings 2004). We note that mobile technologies have unique affordances well suited to support mobile learning; however, we need to first address some challenges that we currently face.

Pedagogical Challenges

The EDUsummIT (International Summit on ICT in Education) thematic working group on mobile and informal learning (Khaddage et al. 2015; Lai et al. 2013; Lewin et al. 2018) has identified a number of pedagogical challenges of mobile learning, and the following discussion will focus on three of them. The first challenge is the need for teachers to reconceptualize learning as mobile (Traxler 2010). The second challenge is the need to develop new pedagogical designs and practices to integrate academic and everyday knowledge across contexts, recognizing that contexts can shape digital practices and digital practices developed in one context may not be readily transferable to another context (Sharples 2015a). The last challenge is the need for students to develop self-directed learning skills to self-manage, learn how to engage in critical reflection, and be resilient in different mobile learning contexts (Khaddage et al. 2015).

The need for a deeper understanding of mobile learning. Currently many teachers only have a superficial understanding of mobile learning and are unaware of its transformative power on learning experiences. This is not surprising, since although digital mobile devices have been widely used by children and youth, they are not yet widely used in schools to support teaching and

learning (Kjartansdóttir and Jakobsdóttir 2016). Even when they are used in schools, teachers often use them to substitute or augment existing practices (refer Puentedura's (2006) first two steps of the SAMR model). They simply follow what they routinely do when using digital technologies in teaching. As pointed out by Traxler (2010), while teachers may see technology as mobile, they do not see learning as mobile. When describing the US mobile learning landscape, Evans (2018) has a similar observation:

The adoption process for the use of mobile devices in the American classroom has followed a traditional technology adoption pattern... Too little emphasis is on the more important aspects of mobile learning usage... that enable and empower new learning modalities and approaches that transcend traditional learning practices. (p. 787)

This is largely due to the fact that teachers do not have a good understanding of the pedagogical affordances of technologies in general and, in particular, the unique affordances of mobile technologies which can facilitate out-of-school learning and add value to academic learning and thus make formal learning more relevant to students (Lai and Smith 2018). As discussed previously, mobile learning should be conceptualized as learning across contexts where different forms of knowledge are located, and this requires a change of the teacher's belief and identity. Erstad (2012) points out teachers need to recognize and value students' prior everyday knowledge and skills which they can draw on to augment academic work. One exemplar approach linking in- and out-of-school knowledge Erstad (2012) suggests is the Funds of Knowledge approach where teachers visit students' homes and communities to understand the knowledge that they have acquired in those contexts, and then use the information to make a connection to the formal curriculum, so as to make learning more meaningful to their students. This boundary crossing empowers students with agency to continue their learning trajectories from home and community to school.

Bjørgen and Erstad (2015) have studied primary students' in- and out-of-school digital

practices, and they found that contexts regulated and structured these practices, and students used digital media in different ways between the two contexts. In their study, Bjørgen and Erstad (2015) reported that out-of-school digital practices were considered by young people as more relevant and interesting, and they “framed school’s digital practices as irrelevant or meaningless for their leisure-time interests in technology” (p. 123). Their study shows that there are strikingly different school and out-of-school digital cultures and practices, and students may experience cultural clashes since there are different expectations from these learning contexts. Rajala et al. (2016) give an example that when using social media after school for formal school work, students expect that because it is formal learning and therefore they would use formal school language in their work, even though it is not the natural language they would normally use with these media. They suggest that young people’s digital practices are context dependent and they are difficult to transfer across contexts. The tension of mixing students’ informal Web 2.0 learning with formal learning has also been observed by Crook (2012), and he suggests that there are four themes of incompatibility between the two forms of learning, namely, inquiry, collaboration, publication, and literacy. It is clear that students’ informal learning experiences often do not fit in with the school learning culture. However, there can also be a semiotic relationship between digital practices in formal and informal contexts, with what students have learned and practiced in school influencing how they learn and practice in out-of-school contexts (Lai et al. 2013).

Implementing mobile learning in school also challenges the role of the teacher as transmitter of knowledge. Allowing students to access and use mobile devices in schools means teachers can no longer monopolize knowledge, and this has implications on the power relationship between the teacher and her students which may threaten the teacher’s identity (Biesta and Tedder 2007). Informal mobile learning also requires stronger learner agency to direct learning as compared to classroom learning where it is largely teacher-directed, with learning materials being prescribed and

learning sequence structured by the teacher. However, this does not mean that the teacher has little role to play in the mobile learning process, since totally unguided learning has been found ineffective (Kirschner et al. 2006; Mayer 2004). This is a question of how to balance the amount of guidance provided by the teacher and the degree of freedom that the student should have in controlling her learning. Unfortunately, the issue of learner agency in mobile learning has not been adequately addressed in the literature (Suárez et al. 2018), and there are epistemological and ontological issues of knowledge creation and transmission that needed further exploration, as suggested by Pachler et al. (2010).

Developing new pedagogies across contexts. In a report on mobile learning, UNESCO (2012) maintains that current pedagogical approaches are not appropriate to support the way the new generation of learners learn and as such an instructional paradigm shift is needed. The tendency for teachers to use new technologies including mobile devices to support existing practices, as pointed out by Erstad and Sefton-Green (2013), may be due to the need to promote standardization rather than develop students’ creativity. How to keep the learner motivated in learning is a challenge, since young people often feel that formal learning is disengaging (Philip 2017). While there is evidence to show that using mobile devices may increase motivation and engagement as compared to using other media in formal learning contexts (Jeno et al. 2018), how to sustain interest and engagement is an issue. We are reminded by Philip and Garcia (2013) that while technologies come with a novelty effect which can generate situated interest, innovative pedagogical designs are needed to sustain students’ interest to engage in deep learning.

Since mobile learning is learning on the move (Jaldemark 2018), a pedagogical challenge is to design different learning activities to “take advantages of different [learning] contexts” (Sharples 2015a). Ito et al. (2013) have provided several examples in their report of how learning can be successfully connected and supported by using a range of digital and mobile technologies. Hyvärinen et al. (2016) have provided an

interesting example of how an extended learning environment involving boundary crossing could be created by teachers in two Finnish primary schools. In their study the teachers firstly identified and recognize students' prior knowledge from informal learning and then planned authentic learning activities by extending academic work outside the school environment in collaboration with local partners. They coordinated with local partners such as flea markets, art projects, and the communal recycling center to create opportunities for learning activities. The teachers involved observed that these out-of-school activities could nurture curriculum and cross-curriculum learning. They also reflected on their practices and learning outcomes and found that the students had developed a range of skills through boundary-crossing activities, as well as gaining an understanding of learning for life and learning in community. Interestingly, this boundary crossing was also transformative for the teachers. Working in out-of-school environments has made them aware of new learning possibilities and shifted their role as a learner. The hybrid learning model proposed by Mikkola and Kumpulainen (2016) suggests that an effective way of boundary crossing is to create collaborative hybrid learning activities so that learners can use their resources from their lifeworlds in formal settings. However, we need to be cautious that in boundary-crossing, there are dangers in "bringing students' everyday life into schools" (Pachler et al. 2010), and the "pedagogisation of everyday life" (Sefton-Green and Erstad 2017), since students tend to resist the blurring of the boundary between academic and personal spaces (Lewin et al. 2018).

Mobile technologies such as smartphones now make one-to-one computing truly possible. However, if teachers use mobile devices to support content delivery in order to personalize learning, they need to realize that on the small cell phone screen, limited packets of information can only be presented at a time, and this chunked nature of information may lead to fragmentation of knowledge and undermine deep learning (Traxler 2010). When designing out-of-school tasks for informal learning using mobile technologies, teachers also need to pay attention to some psychological

challenges with learning on the move (Jaldemark 2018). Terras and Ramsay (2012) have identified five challenges, namely, the context-dependent nature of memory; human cognitive resources are finite; cognition is distributed and learning is situated; metacognition is essential; and individual differences matter. To tackle these challenges requires a design of informal learning tasks that allow the learner to successfully manage their learning in a distractive environment.

Mobile learning is often associated with inquiry-based learning conducted outside school. We are reminded by Sharples (2015b) that linking academic work undertaken in the classroom with work that students do in an out-of-school setting such as a museum can be demanding and unpredictable, and the teacher needs to consider how to maintain a continuity of learning across both contexts. There is a need for orchestration:

Orchestration of learning as the central issue in supporting a pedagogy of inquiry-based learning that encompassed teacher-initiated inquiry in the classroom, learner-managed investigation at home or outdoors supported by mobile devices, and group activity back in the classroom to synthesise and share findings. (Sharples 2015b, p. 50)

Orchestration also means an awareness of the distraction that the use of mobile devices would bring to the classroom. However, discouraging students from using mobile devices altogether during class time is an ineffective strategy even though distraction from multitasking is a real concern (Fuchs and Woessmann 2004). Whether multitasking is merited has been debated in the literature. In some countries, for example, Germany, multitasking skills are included in the school curriculum (Spitzer 2014). However, it is well recognized in cognitive psychology that multitasking is not an effective learning strategy when students are asked to perform complex cognitive tasks when focused attention is required (Lee et al. 2012).

Developing students as mobile learners. School learning is highly structured, with content being prescribed by the curriculum, and the time schedule for learning inflexible. For everyday learning, it is completely the opposite. Learners have no curriculum to follow; there is no structure

nor tutor to guide them (Lai 2018). To take advantage of the out-of-school learning opportunities facilitated by mobile devices, students firstly need to understand the value of informal learning, that learning is lifelong, life-deep, and life-wide (Cross 2006), and secondly develop the self-directed and collaborative learning skills required to manage informal learning successfully. As reported by Boticki et al. (2015) in their study of mobile learning with primary students, without teacher guidance students only had limited engagement in using mobile technologies for self-directed learning activities. In designing learning activities across contexts, teachers therefore need to design knowledge building activities to support learner agency where students would develop their own questions and solve problems as a community (Khaddage et al. 2015). Mobile learning also requires a change of assessment practices to avoid standardization of the learning tasks and outcomes (Hwang and Chang 2011). Although undertaken in higher education context, Lai and Smith's (2018) study has suggested four ways that teachers can induce their students to engage in informal learning. Teachers can make their classes more interesting which may trigger students' self-directed and follow-up learning in informal contexts. They may encourage students to be more independent and take responsibility for their learning. Teachers may also emphasize on informal and lifelong learning in class, provide learning resources to foster it, and support students to develop new learning skills such as collaborative knowledge building. Lastly, they may model informal learning in their class.

Research Challenges

Conducting TEL research has always been challenging, and studying mobile learning adds to the challenge. In the last 30 years, while TEL research has flooded the field, sadly, as pointed out by Selwyn (2012), the field of educational technology "has grown into a notoriously sloppy area of scholarship – brimming over with lazily executed 'investigations' and standalone case studies, while also tolerating some highly questionable thinking" (p. 213). In addition, there is a problem with reporting. Rather than reporting what has

actually happened in the classroom, many technology advocates published speculative works of what they thought should have happened and thus created the impression that the use of digital technologies in learning and education was vibrant and successful (Selwyn 2010). As a result, despite the excitement on TEL in general, and in mobile learning in particular, so far there is a lack of adequate evidence to support what Kozma (2008) called the "strategic educational ICT policy rationales" (p. 1085), and there is little evidence to show that so far ICT has advanced educational reform.

We find that implementation failures often follow from large-scale investments on digital technology. For example, the recent large-scale uptake of the iPads in California schools ended up in chaos (Philip 2017). The lack of credible evidence of success in technology use in education is alarming. When commenting on the effectiveness of mobile learning, Sharples (2013) maintain that "over the past ten years mobile learning has grown from small-scale studies to large national and international projects, but it still lacks an evidence base of comparative studies and research into large-scale deployment" (p. 5). Sharples' comment on mobile learning research is not surprising because even after over 30 years of research on TEL, with numerous studies being conducted in every school subject, Lawless (2016) points out recently that "taken as a whole, research on the effectiveness of general contemporary technologies does not yield enough decisive evidence to support conclusive proof of their effectiveness in improving educational outcomes" (p. 5). Similarly, according to an OECD (2015) study, there is a lack of evidence to show "appreciable improvements in student achievement in reading, mathematics or science in the countries that had invested heavily in ICT for education" (p. 15).

Scholars have identified problems in measuring technological effects in media comparative studies (e.g., comparing content delivered by a mobile app and a book). It is argued by Selwyn (2011) that since technology is embedded in a complex sociopolitical and economic system, one cannot take TEL out of its contexts and measure learning outcomes in isolation. Trying to

measure learning outcomes with any “degree of confidence or certainty over a discernible ‘cause-and-effect’ relationship between technology and learning is nigh on impossible” (p. 84). This points to the importance of studying the learning environment, not just the technology, or even the pedagogy. As pointed out by Clark et al. (2016), while technological applications/software provide new affordances, it is how they are used, and how the learning environment is designed which “leverage those affordances” (p. 116) that would affect learning outcomes.

While there are already huge methodological challenges in studying TEL, it is even more challenging when mobile learning is to be investigated across time and space, and there is a learning trajectory that has to be tracked. Thus, as commented by Leander et al. (2010), “a key challenge in researching mobilities involves a critical reassessment of the space–time shape and assumptions of research methods, assumptions, and modes of analysis” (p. 343). They maintain that there are difficulties in researching mobile learning because we are not studying a single event or site, but multiple events in multiple sites that have to be researched simultaneously, and there is a need to investigate the interaction and relationship between time and space. It is not just a question of what, when, and how data are to be collected; the complexity of the data also makes meaning-making difficult. For example, in conducting a seamless science inquiry project using mobile devices, Song and Ma (2013) commented that it was a demanding task to track the learning process, due to “the limited screen size, and the mobile nature of the activities, learning can occur in constantly changing contexts such as home, school and other spaces,” and there is a need “to examine holistically and “re-construct” learning occurring in different contexts” (n.p.). The lack of theoretical frameworks in mobile learning research adds to the difficulties (Baran 2014), since the majority of the mobile learning case studies were either not grounded in learning theories (Bano et al. 2018) or were based on behaviorist learning designs, involving, for example, drill and practice activities (Crompton et al. 2018). Also, these case studies were mostly

comparative studies investigating the effects of mobile technologies, and data were collected primarily from formal settings (Crompton et al. 2018). Some promising pathways to tackle these challenges may include using the learning lives approach to follow the learner’s learning trajectories across everyday life (Sefton-Green and Erstad 2017). Design-based research is also promising since it is a more holistic and participatory approach (Amiel and Reeves 2008). Ethnographic studies of different contexts may also be undertaken (Lewin et al. 2018), but as warned by Leander et al. (2010), “the ability of our empirical work to keep up with rapid changes in technology and, in particular, to account for the effects of these changes in the everyday lives of children and youth through ethnographic studies is called into question” (p. 374).

There are ethical issues specifically related to mobile learning research which are challenging. Wishart (2018) reminds us that the fluidity and unpredictability of mobile learning contexts and activities may create some unique ethical challenges. For example, Traxler and Bridges (2005) have suggested several ethical difficulties that may arise in mobile learning research, including the need to gain ongoing informed consent; anonymity of identity and confidentiality of data may not be fully kept in an online context; the participants may inadvertently access inappropriate materials online; and in cross-cultural studies, the economic and cultural diversity of the participants may create different expectations.

Policy Challenges

There are many structural constraints in using mobile devices to support learning across contexts. Schuck et al. (2017) remind us the inflexibility of the physical learning environment of the school and the rigidity of the temporal schedule of the curriculum as barriers. Lewin et al. (2018) point out the need to reform the standardized and highly prescriptive curriculum and high-stakes assessment which undervalue informal learning and discourage knowledge gained from out-of-school contexts using mobile devices being transferred and recognized in the formal school environment. In their study, Lewin et al. (2018) further

argue that since mobile learning is often spontaneous, flexible, and incidental, it often does not align well with traditional learning goals and objectives. Thus the challenge is how to develop pathways to recognize and accredit self-directed mobile learning undertaken in informal contexts.

This highlights the importance of professional learning and development. It has been well documented that effective teacher preparation and in-service professional learning and development are essential to drive change and innovative practices (Fullan 2015). Mobile learning requires a reconceptualization of learning and change of beliefs, which requires ongoing support and professional learning and development. However, so far little attention has been paid on supporting teachers of how to implement mobile learning in their class (Baran 2014). For example, as pointed out by Kukulska-Hulme et al. (2011), even in Europe where mobile learning has been heavily promoted in the last decade, there is little attention on developing teachers' pedagogical understanding of mobile learning. Technological training has also been neglected. While teachers do not lack experience and skills of using their own mobile devices such as smartphones, they lack technological skills in using new mobile devices for educational purposes (Pachler et al. 2010). How to motivate teachers to change and adopt mobile learning in their practice remains a significant challenge which has not been taken up seriously.

Many schools have adopted the Bring Your Own Device (BYOD) policy in order to promote mobile learning. This policy means students often are required to purchase their own personal devices, thus shifting the hardware and software costs to the parents. This has created an equity issue if parents cannot afford the costs. Also, this policy may create some new management or technical challenges. While BYOD may help reduce some of the technological and student training costs for the school, there are increased infrastructural costs for Internet connectivity and teacher training, as well as management and technical support challenges as a variety of devices may be used by the students (Khaddage et al. 2015).

Cyberbullying both in- and out-of-school has now been routinely reported in the media, with a rising trend in some countries (Eden et al. 2013). As defined by Kizza (2016), cyberbullying is the use of the Internet and mobile technologies with the intention of harming another person, and there are different types of cyberbullying, such as harassment, flaming, exclusion, outing, and masquerading. According to a recent Pew Research Centre national survey (2018), 59% of the American teenage respondents had experienced some form of cyberbullying, and the most common type of cyberbullying was offensive name-calling (42%). Other forms of cyberbullying included spreading false rumors (almost a third), had someone other than a parent tracking where they were (over one-quarter), and being the target of physical threats (16%). It is alarming that in this survey, 63% of the respondents considered cyberbullying a major problem, and 58% felt that their teachers had failed to address this issue. The need for a school-wide policy to inform teachers of how to tackle cyberbullying is clearly shown from the findings of this survey. In fact, in a study surveying the perceptions of cyberbullying of 328 school teachers in Israel, Eden et al. (2013) found that just over one-third of them were confident of dealing with cyberbullying cases, probably due to the lack of understanding of the issue (only 20% of the teachers were confident of identifying cyberbullying), and a majority of the teachers (65%) would like to learn more about cyberbullying. However, it is not clear whether the prevalence of mobile devices has led to the increase of the risk of cyberbullying. After reviewing the literature on the risks of online aggressive behaviors, Livingstone and Smith (2014) concluded that "the risks of cyberbullying, contact with strangers, sexual messaging ('sexting') and pornography generally affect fewer than one in five adolescents [and] despite the rise in children and young people's use mobile and online technologies, there is little compelling evidence that online risks are increasing commensurately" (p. 645). Nonetheless, they recommended that practitioners should be trained to understand and recognize the online risks

associated with the use of mobile technology and develop interventions and policies to mitigate these risks.

Conclusion

This chapter began with a discussion of the changing understanding of mobile learning in recent years, highlighting the recognition that context rather than technology should be the distinctive focus of mobile learning, but we also note that the techno-centric mentality of “what is being done is... simply because it can be done” (Norman 2013, pars. 16) is still pervasive. While there is no doubt that the unique affordances of mobile technologies are important in supporting certain learning strategies such as situated and constructivist learning, in conducting mobile learning research, we should be cautious not to focus just on the technological and pedagogical factors. We should also consider the broader sociopolitical and economic contexts where educational activities are embedded (Ito et al. 2013; Selwyn 2012). We also must admit that even after mobile learning has been around for over 20 years (we follow Norris and Soloway’s (2018) use of 1997 as the starting of mobile learning when the Palm III PDA first appeared in the educational scene), we still do not know much about how it can be effectively designed, implemented, and evaluated in and across learning contexts, and there are a number of pedagogical, research, and policy challenges that we need to tackle if mobile learning is to be successfully implemented. To tackle these challenges, we are reminded by Selwyn (2012) that we must be more critical, and there is a need to examine “how digital technologies (re)produce social relations and in whose interests they serve” (p. 219).

Cross-References

- [Augmented Reality in Education, Scope of Use and Potential](#)
- [Flexible and Distance Learning](#)
- [Mobile Learning](#)
- [Mobile Learning and Ubiquitous Learning](#)

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Mobile Video

- [Video-Enhanced Feedback](#)

Model

- [Design in K-5 Programming Projects, Role of](#)

Model Driven Design

- [eXtreme Model-Driven Development \(XMDD\) Technologies as a Hands-On Approach to Software Development Without Coding](#)

Model-Driven Development

- [Modeling of Games and Game Strategies](#)

Modeling of Games and Game Strategies

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Synonyms

[Computational thinking](#); [Low-code application development](#); [Model-driven development](#); [No-code application development](#); [Problem-based learning](#); [Problem-based learning putational thinking](#); [XMDD](#)

Introduction

Developing, managing, evaluating, and comparing strategies for problem-solving are central skills when handling demanding and complex problems, both in computer science and many sectors of the economy. Such strategies often exist in the mind of single individuals and are often based on intuition, experience, and personal knowledge. Especially when working in teams, it is a big challenge to find common means to clearly formulate, communicate, and evaluate strategies. Games and simulations are widely used nowadays to train specific skills in teams. Notable examples span a growing variety of professional areas. In emergency medicine and disaster management, for instance, the online European Master in

Disaster Management (<https://www.dismaster.com>) features the use of simulations and interactive media as an essential technology to bring together its global cohort of participants and have them cooperate in groups to solve complex collaborative scenarios. Crew training for aerospace missions, pilot training, and assessment have included for a long time simulations and games, and many new approaches to smart and connected health, smart manufacturing, and collaborative design use games or game-like simulations to train situated behaviors of increasingly complex nature. Such approaches have been called *serious games*, or applied games, for games designed for a primary purpose other than pure entertainment. This term is now widespread, although the traditional gaming industry dislikes it.

It has been confirmed by various studies that games and simulations have a positive impact on achieving learning goals (Vlachopoulos and Makri 2017). As remarked in (Juan et al. 2017), “the evolution of computer technologies, together with the increasing speed of Internet-based communications, has promoted the use of simulation software and serious games in higher education. These technological and methodological tools can significantly enrich the learning experience in almost any knowledge area. In particular, they will have a significant impact on how the learning process is performed in the so called Science, Technology, Engineering, and Mathematics (STEM) education.” Furthermore, games typically make attractive and engaging course topics for students of all ages (Juan et al. 2017); on balance, results indicate that games and/or simulations have a positive impact on learning goals (Vlachopoulos and Makri 2017) and game development allows students to experience various aspects of software development by systematically exploring the mechanics of a game. Modeling games and game strategies with **dedicated modeling environments** instead of implementing them with conventional programming languages or by just using pre-existing game engines focuses the attention on problem-solving. Students concentrate on understanding and managing the domain-specific essentials of the strategy without having to deal with the

technicalities of a programming language and coding. Not much literature is available yet on model-driven or model-based game strategy design and game development, so it is still difficult to quantify and give a systematic picture of their use in educational practice.

This entry presents and discusses three selected examples of short courses described in recent literature that use modeling of games and game strategies as a teaching tool (section “[Modeling of Games and Game Strategies as a Teaching Tool: Examples](#)”). It then discusses aspects relevant to the educational context in which they are used (section “[Discussion/Evaluation](#)”). Section “[Conclusions and Outlook](#)” concludes the entry with a summary and perspectives for the future.

Modeling of Games and Game Strategies as a Teaching Tool: Examples

This section reports on three examples of game and game strategy development that have been successfully used as modeling tools to teach computational thinking concepts, for which detailed accounts can be found in recent literature. The three examples are the ConnectIT game, used as a computational thinking approach to strategy design (Bakera et al. 2009); the ChainReaction game, used successfully in summer camps for girls (IEEE 2016; McInerney et al. 2017); and a virtual world application to serious games in business and entrepreneurship based on Second Life ([Science in 3D – BMBF-Projekt; Lehre in Virtuellen Welten](#)).

They all use the XMDD paradigm (eXtreme Model-Driven Development) (Margaria and Steffen 2008) introduced first with the jABC modeling framework (Steffen et al. 2006; jABC) and later in DIME (Boßelmann et al. 2016). The paradigm is summarized in the entry “eXtreme Model-Driven Development (XMDD) technologies as a hands-on approach to software development without coding” of this Encyclopedia ([Margaria and Steffen](#)). jABC is a framework for model-driven development of service-oriented applications. It provides an intuitive yet powerful representation of processes in terms of service

orchestrations (see Fig. 1) that use libraries of domain-specific building blocks as a reusable DSL. Applied to game strategies, this means that simple yet immediately functional and nontrivial example strategies can be created from a taxonomy of pre-defined domain-specific building blocks. In this entry they concern games, but other domains in use include scientific workflows in bioinformatics, business processes, text analyses in computer linguistics, healthcare processes, workflows in smart manufacturing, and several industrial applications in projects. After instantiation, each such component can be parameterized depending on the current context of use.

ConnectIT

ConnectIT (Bakera et al. 2009) was developed in 2008–2010 using jABC and repeatedly used in week-long CS summer camps with school pupils (grade 10–12), to teach computational thinking by means of strategies for the well-known connect-four game: Two players throw in turn a token in a board of seven columns and six rows. The token falls down to the lowest unoccupied position in the column. Each player plays with its own token color. The player that gets a group of four connected tokens (either horizontally, vertically, or diagonally) wins the game. The game is drawn when the board is full and no player won.

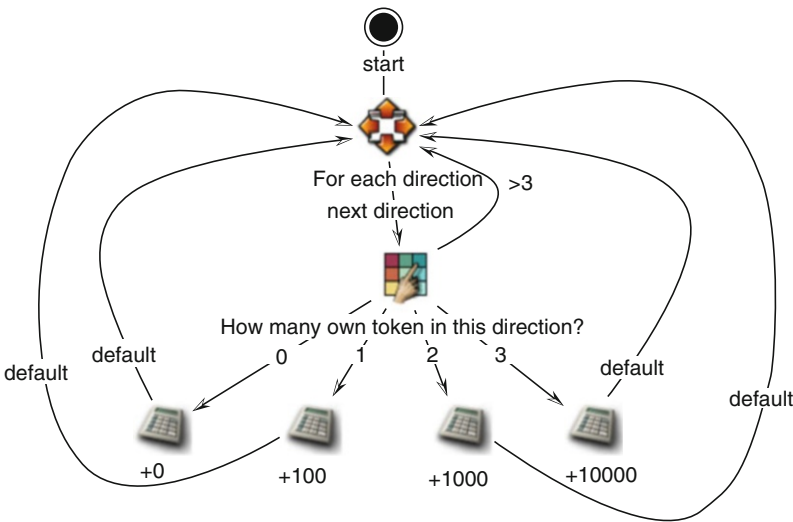
Strategies for this game were first studied by Allis (1988), who followed a knowledge-based approach. In ConnectIT, it is deliberately not possible to build the perfect strategy identified by Allis. Instead, the provided building blocks allow for the construction of strategies that analyze patterns on the board, and the goal for the students is to build the best (imperfect) strategy to win the competition with their peers.

Figure 1 shows a simple and intuitive yet powerful representation of a strategy called *Average Joe*: It will give preference (expressed by a higher score) to cells that already have tokens of the same color nearby, thus increasing the chance of getting four in a row. Technically, the strategy is an orchestration of services that are the building blocks of a ConnectIT DSL. Once a strategy is created, having a measure at hand that allows for both concise and easy evaluation and comparison of several strategies offers two benefits:

- 1. First, a fast validation technique of the overall outcome reveals errors at an early development stage.
- 2. Second, the learning curve to become comfortable with the strategy under development is greatly improved – since strategies’ behavior and impact depend on highly context-sensitive fine-tuning of parameters.

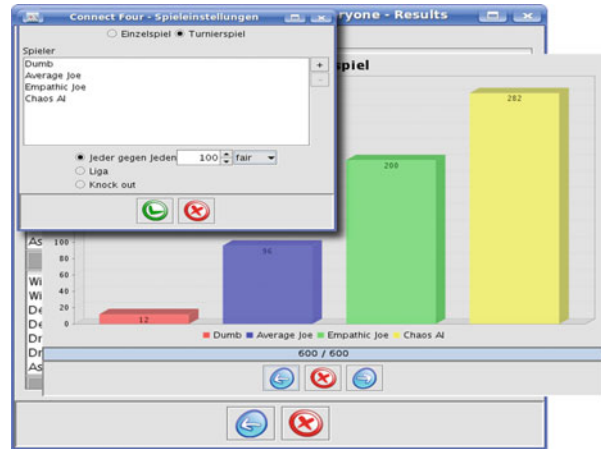
Modeling of Games and Game Strategies,

Fig. 1 A simple strategy for ConnectIT (“Average Joe”). (From Bakera et al. 2009)



Modeling of Games and Game Strategies,

Fig. 2 Evaluation of a ConnectIT strategy and snapshot of the tournament model. (From Bakera et al. 2009)



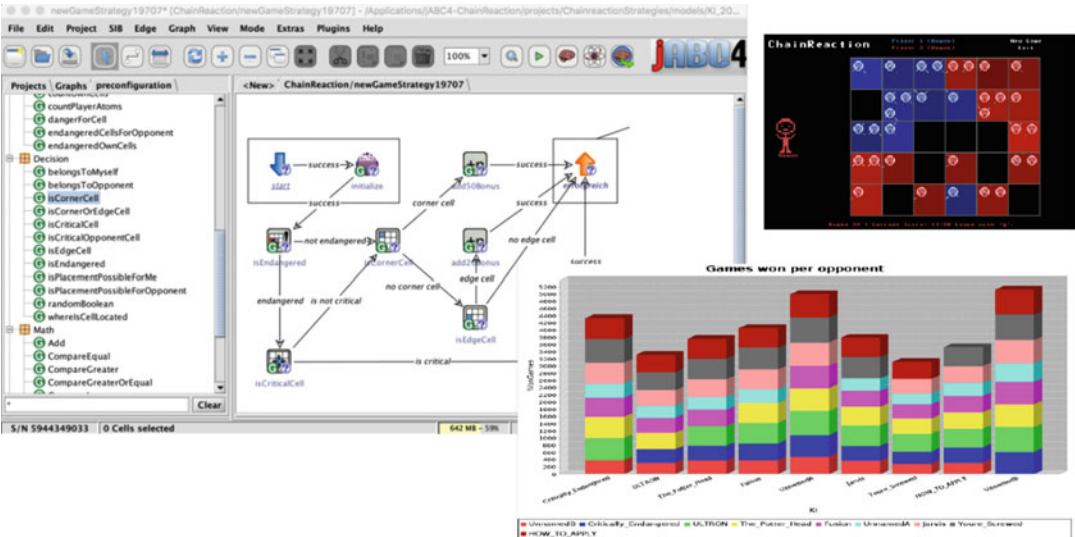
In the connect-four game, considering the adversary's possible moves additionally to the own ones also requires deciding which (relative) weight this information carries in the decision of the next move. Accordingly, ConnectIT provides an integrated evaluation functionality of the strategies and of their parametrizations in terms of tournaments. The effects can be studied in depth by playing several different kinds of tournaments (round robin, everyone against everyone, direct elimination, etc.) with (virtual) users that adopt the one or the other strategy. Each tournament returns a graphical presentation of the results (see Fig. 2 for a snapshot) and details about each match in the tournament. Combining several evolution steps in strategy development into a tournament enables students to directly witness and quickly pinpoint the effects of the decisions taken and to improve their strategy. This capability directly reveals whether a supposed enhancement of the strategy also yields a significant improvement of the strategy's competitiveness.

ChainReaction: Computing Camps for Girls

Increasing the number of female students in ICT-related university courses has been a major concern for several years. In 2015, McInerney et al. offered for the first time a girls-only computing summer camp, as a new component in the education and outreach activities to foster students' interest in computer science (IEEE 2016; McInerney et al. 2017). Two 3-day camps for

postprimary girls aged 14 and up were ran during the summer of 2015 at the University of Limerick. In the schedule for 3 days, the development of game strategies for the ChainReaction board game occupied ca. 2 days, including the students' final presentations. The other sessions were devoted to invited speakers from the industry and academia and to a robotics session with the NAO robot.

Modeling executable strategies for the ChainReaction board game was a major component of the program (blue sections in the table). ChainReaction (<http://chainreaction.freewarepoint.de>) is a strategy game for two players, who play against each other on a special 6x5 board, both trying to initiate chain reactions of atoms to conquer the whole board and win the game (see, e.g., the "Introduction to ChainReaction" page (<https://hope.scce.info/chainreaction/>) for a detailed description of the rules). The development of the game strategies to be followed by a computer player takes place in a specially prepared version of the jABC modeling framework (Steffen et al. 2006; jABC), which supports the intuitive, graphical development of flow-graph structures to define the behavior of a system. Figure 3 gives an impression of how the modeling of ChainReaction strategies with jABC works: The component library on the left contains the building blocks from which the strategies are assembled. The strategies focus on defining how the score for a cell on the board is to be computed.



Modeling of Games and Game Strategies, Fig. 3 The ChainReaction game, modeling of ChainReaction strategies with jABC, and results of a tournament played between nine strategies

The framework then evaluates the strategies for all cells and places the next atom into the cell with the highest score (or, if there are multiple cells with the same highest score, randomly choosing one of them).

The framework, which is very similar to the successful jABC version for the modeling of game strategies for the more popular ConnectIT board game described earlier in this entry, combines an easily accessible application domain with a quick sense of achievement: The first game strategies are typically ready to run after a 30-minute introduction to the modeling tool. Students can then work on incrementally improving this starting strategy. They also get immediate feedback about the quality of the results by playing against their own strategies or by letting the strategy play against other computer players. As such, it provides a very motivational framework and a fun and lightweight learning-by-doing way to acquire and practice computational thinking skills.

In the first camp session, participants were introduced only to the basic ChainReaction game and had some time to play and familiarize themselves with it. The girls paired up on one computer for this exercise and worked together in these pairs for the rest of the camp.

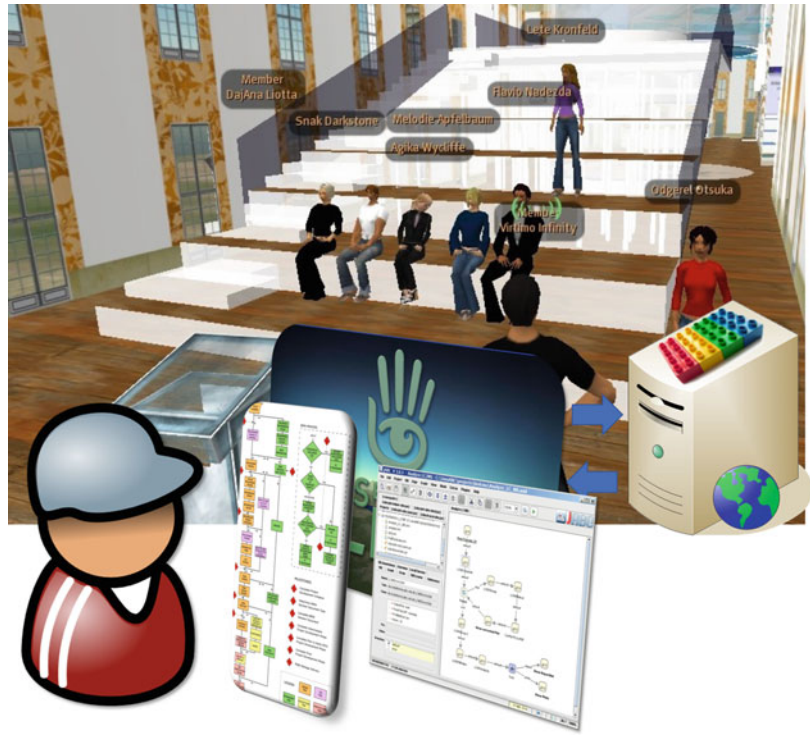
The next session was designed to foster more strategic thinking about the game. The task for the girls was to write down – simply on paper – how they had actually played the game, that is, which strategy they had followed to decide where to place their atoms. The groups then exchange strategies on paper, and each group tried to play strictly according to what the other group had written down. In a very entertaining way, this demonstrated the importance of formulating precise and unambiguous instructions.

The last session of the first day introduced the modeling tool and taught students how to model and execute their first simple ChainReaction strategy. The remainder of this session and the ChainReaction sessions on Day 2 were focused on the development and improvement of game strategies. At various intervals additional hints and suggestions helped the girls improve their strategies, which became quite sophisticated toward the end of the second day.

In the last ChainReaction session, on the third day, every group had to select and submit their final strategy. They entered a final tournament with all strategies playing against each other to determine the best one. The bar chart in Fig. 3 (lower right) shows the results of a tournament of nine strategies.

Modeling of Games and Game Strategies,

Fig. 4 Serious games in Second Life: business processes and workflows act in the virtual 3D experience



Serious Games: The Potential for Business Applications

The development of strategies and strategic behavior is most relevant to entrepreneurs or management teams that have a clear vision and mission for their business and are in the process of developing primary strategies. The development of a suite of strategies is an iterative process and involves circular thinking on the basis that optimal strategies will evolve gradually and be very interdependent. Accordingly, the best way to test strategies is to define, model, and test them. By applying the ConnectIT approach to simulate business-related strategies, entrepreneurs and managers can easily evaluate their strengths and weaknesses in strategic planning and behavior (Fig. 4). Additionally under virtual conditions, the learning process for the managers and entrepreneurs is risk-free and costless. Furthermore, the results of a chosen strategy can be analyzed systematically and improved over time.

A venture is most prone to failure during its first three or so years of operation – the so-called valley of death (Murphy and Edwards 2003).

A key to getting through these early years is to avoid the obvious mistakes. Generally speaking, businesses fail for significant and substantial reasons which are often very evident to outsiders. Insiders often fail to see them because of their closeness, determination, and so on.

These issues were reflected by the project *Science in 3D* (Lattemann and Stieglitz 2008) at Potsdam University. It employed a virtual world environment, Second Life, as an innovative tool for knowledge transfer for train entrepreneurs in the sector of biosciences. virtual worlds enable, thanks to their 3D environment, new ways of communication, collaboration, and cooperation. The level of interactivity of virtual worlds is higher compared to other web applications based on plain text, voice, or 2D presentations. Users in virtual worlds are represented by 3D avatars.

In this 3D training camp, entrepreneurs had to go through the whole cycle of a venture including selling products to customers. As Second Life had at that time a quasi-real economy, with an own currency and about 100,000 visitors daily who may act as customers, entrepreneurs could

easily test their venture skills. The central part of this educational experience was the phase of “managing, growing, and ending the new venture.” This phase includes the development of entrepreneurial strategy in the field of generating and exploiting new entries, growth strategies, and strategies for accessing resources and so forth (Hisrich et al. 2005). The project intended to provide simulations of the development of these kinds of strategies by implementing a ConnectIT-like approach for these strategies on a 3D basis in the virtual world. The one-thing approach to business process modeling in the jABC (Margarita and Steffen 2009) made this transfer to the business context easy and intuitive.

Discussion/Evaluation

If schools are offering “computers,” what is taught in schools varies widely and can include HTML/web design, ECDL, browsing the web, typing, Scratch, GIMP, as well as working with Microsoft Word and Excel.

Quick Start and High Productivity

Model-based games like ConnectIT and ChainReaction combine an easily accessible application domain with a quick sense of achievement: The first game strategies are typically ready to run after a 30-min introduction to the modeling tool. Students can then work on incrementally improving this starting strategy. They also get immediate feedback about the quality of the results by playing against their own strategies or by letting the strategy play against other computer players. As such, the XMDD-based approach to games provides a very motivational framework and a fun and lightweight learning-by-doing way to acquire and practice computational thinking skills.

Note that the ability to be productive quickly is an essential trait mentioned when choosing scripting and interpreted programming languages like Python, PHP, or Lua over traditional programming languages like C, C++, or Java. The perceived simplicity of the language and the

resulting improved confidence of the students are essential to avoid frustration due to struggle with complex environments.

In these applications of XMDD, the students end up mastering the essential concepts of a programming language through the domain-specific language of the game and are free to concentrate on the strategy design rather than on coding-level issues.

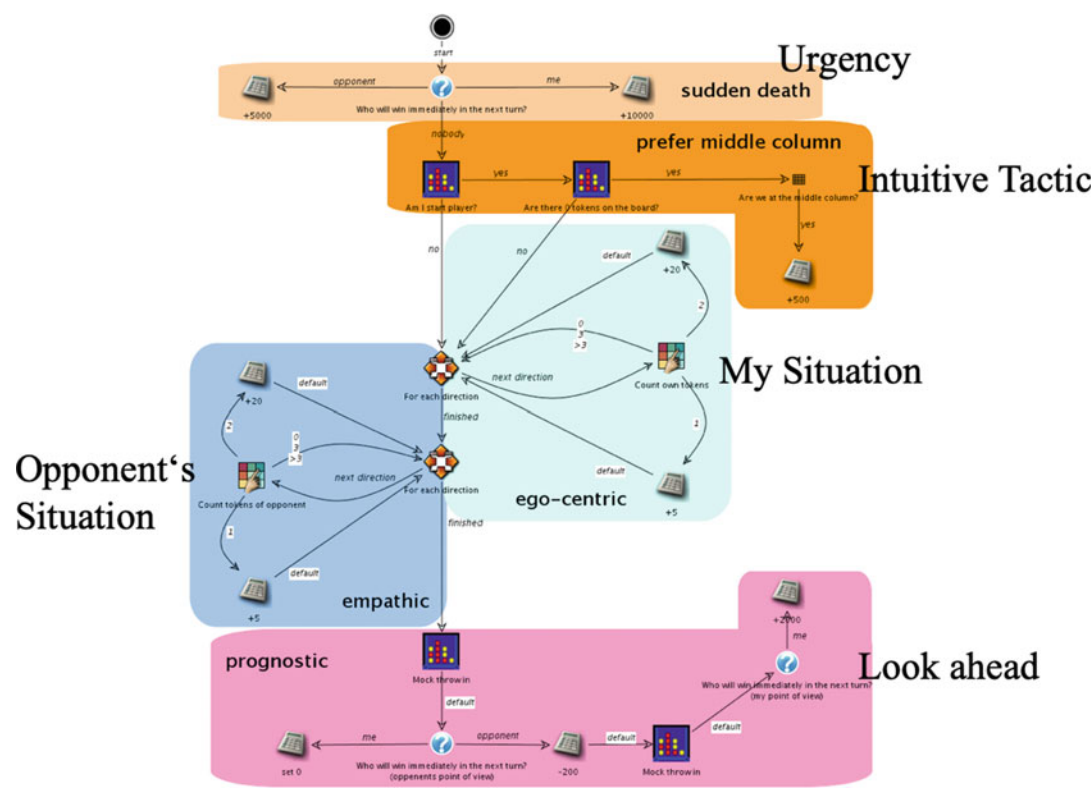
Ability to Express Complex Strategies

ConnectIT was used and refined in several rounds of the Do-Camp-Ing initiative (**Do-Camp-Ing; ConnectIT**) and in 1-day workshops (“Schnuppertage”) (<http://connectit.cs.tu-dortmund.de/blog/>), with heterogeneous groups of pupils who had no previous computer science training.

The pupils were able to build really competitive strategies like the one shown in Fig. 5 just by leveraging their intuition and knowledge about the connect-four game.

The *Chaos AI* strategy (name chosen by the two pupils who developed it) is very competitive. It contains the *Average Joe* component but adds a defensive part which considers the opponent’s tokens. Furthermore, *sudden death* initially checks whether a throw in the current column leads to an immediate win. If so, it scores the column appropriately. Whenever there are no tokens on the board, the strategy *prefers the middle column*, a direct implementation of a rule of thumb (like the favored center position in the tic-tac-toe game) that emerges as a best practice when playing.

After counting the own and opponent’s tokens on the board, the *prognostic* part of the strategy explores the near future via a mock throw-in at the current column. The mock throw-in building block exchanges the roles of the player and opponent; thus, all subsequent building blocks must be treated from the opponent’s point of view (until another mock throw-in appears, as in our case). After the first mock throw-in, the strategy checks whether the opponent would win. In this case, one would help the opponent, so the score for the



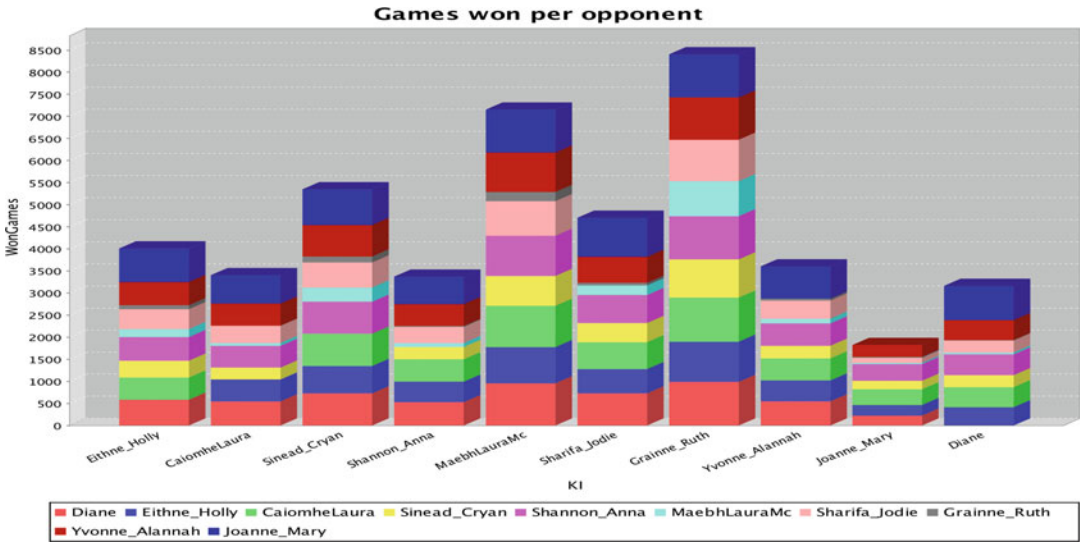
Modeling of Games and Game Strategies, Fig. 5 Chaos AI: A ComplexStrategy (by pupils)

current column is 0. The other case is first punished with a moderate malus (−200 points), as one would build a too obvious triple that is likely to be blocked by the opponent. Second, another mock throw-in follows in this case (and the roles are switched again). If one would still win in this situation, the column gets a high score, as this indicates a catch-22.

Another approach for describing games in a concise manner was developed by the Stanford logic group and is termed game description language (Genesereth and Love 2005). Its main purpose is the description of games including the rules, the board, the players, and their interplay. However, the lisp-like notation of the language that in fact describes a state machine lacks in a graphical and understandable representation. For instance, a description of the connect-four game takes about 150 lines of code.

ChainReaction: The outcome of the tournament in the girls' camp is shown in Fig. 6. On average, the 24 strategies submitted to the final tournaments of the camps consisted of 19.16 building blocks (median 16, standard deviation 8.85) and had a McCabe number of 6.92 (median 7, standard deviation 4.13). The McCabe number (Murphy and Edwards 2003) gives the number of linearly independent paths through a process model and is commonly used quantitative complexity measure for software. That is, although not being very large, the submitted strategies were by no means trivial and contained

various decision/branching points that create complex program flows, which is reflected by the McCabe number. With regard to readability and maintainability, typically a McCabe number of 10 is considered to be the upper acceptable limit of a program's complexity. The average McCabe



Modeling of Games and Game Strategies, Fig. 6 ChainReaction: tournament results (from [WCCE])

number of the strategies is clearly below this threshold, indicating that they are indeed at a very comprehensible level.

- In the **serious games** context, originally the most important aspect was the ability to model what-if scenarios, more than the 3D enactment of the scenes. The models were used to express and test hypotheses, to examine the consequences of decisions, and to validate properties and “rules” of the strategic decision-making under consideration. Two lessons were learned from this experience:
- The avatars and the simulation engine of Second Life were intriguing but not powerful enough to offer a realistic total immersion experience. Today’s gaming engines are much better, and they are in fact supplanting dedicated simulators in a number of applications where augmented reality and an immersive experience play a role. A recent example is the remote action of a technician directing a local crew to perform maintenance operations on equipment.
- Modeling of the business decisions and strategies was useful and valuable also

independently of the virtual world experience. In fact a new line of application of models was born from this experience, concerning the design and evaluation of business models (Boßelmann and Margaria 2014) using wizards to “direct” and guide the business user. Most recently this has evolved into a methodology for customization through knowledge sharing and configuration within enterprises (Steffen et al. 2016) and to systematically support decision-making through the hierarchical integration of heterogeneous business models (Steffen and Boßelmann 2018).

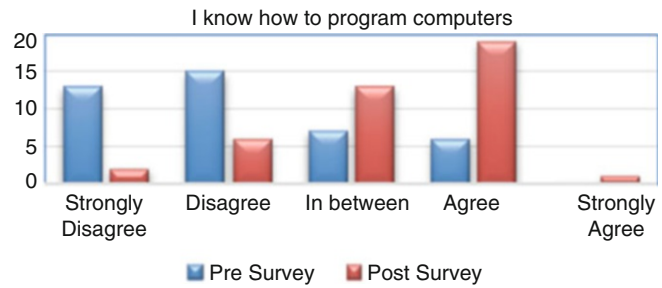
Impact of the Camps: Academic Exposure/ Career Perception

In order to evaluate and assess the impact of our camps, we administered surveys at the beginning and at the end of the camps.

At the beginning students were asked if they had ever written a computer program. Fifty-one percent stated they had not written a computer program before, 26% of participants had written a computer program, and 23% did not know if they had written a computer program. As Fig. 7 shows, the participants’ perceived ability to know

Modeling of Games and Game Strategies,

Fig. 7 Survey results on “I know how to program computers”
(ChainReaction)



how to program computers clearly increased between pre and post survey. Similarly, in our post survey, 95% of the students agreed and strongly agreed that they know more about computing as a job because of the camp. After the camp, we also asked the participants what they liked best about it and why, what they liked least and why, and what changes they would make to make it better.

One female participant in the mixed camps said: “I love the experience and the people even though we were split up in to groups and I was the only girl in the group I still made friends.” Interestingly, when this student was asked about what she liked least about the mixed camps she said: “I didn’t dislike most things the only thing I would change is putting at least one other girl into the group that I was in.” This suggests that the young girls simply might feel uncomfortable being the only female in a group, and female-only or better balanced mixed-gender groups make them feel more comfortable.

Based on the participants’ responses to the questionnaires, the girls-only camp was a very positive experience for them. Students’ self-perception that they are good at computing and their perceived ability to know how to program increased by the end of the 3-day camp. In terms of the perception of computing as a career, participants knew more and were more positive about the field as a result of the camp. The answers to the survey questions also align well with the instructors’ impression that the students had an enjoyable time while at the same time confirming that they learned a lot. The enthusiasm of the students can also be viewed in the video that was

created from footage shot by the students on the last day of the camp ([Google RISE](#)).

The Google RISE funding award for the girls-only camp enabled specific actions to raise awareness about underrepresentation of females in particular.

Conclusions and Outlook

The development of specific offers for secondary school students has become a substantial part of universities’ outreach and science communication activities in the last years. In order to be successful, they need to address attractive (or even fun) topics, which at the same time enable the students to learn something that is usually not part of their curricula.

A game-making project can significantly influence male and also female learners’ attitude to computing (<https://www.tandfonline.com/doi/full/10.1080/08993408.2013.774155>). A structured approach to training open-ended problem-solving can be of fundamental importance to nurture an independent but methodologically sound problem-solving (<https://ieeexplore.ieee.org/document/7344088/>), and the use of concrete tasks, for example, using LEGO Mindstorms, to engage students on algorithm design has proven successful for a long time (<https://ieeexplore.ieee.org/document/6685052/>). Games are more abstract, yet they typically make attractive course topics for students of all ages (IEEE 2014). They are also very suitable to address various aspects of software development, for instance, by looking more systematically at their mechanics, as we do with

the development of strategies for computer players. The ConnectIT and ChainReaction workshops combine an easily accessible application domain with a quick sense of achievement: the first game strategies are typically ready to run after less than 30 min after the introduction to the jABC tool. Students can then work on incrementally improving this starting strategy. The students also get immediate feedback about the quality of the results by playing against their own strategies or by letting the strategy play against other computer players. Summarizing, it is a very motivational framework that provides a fun and lightweight way to acquire and practice computational thinking skills.

Concerning ConnectIT, this experience was extended to an interdisciplinary project in the project/seminar “Strategies in virtual worlds” for students and graduate students of CS, business and management, and biology at the University of Potsdam. There, ConnectIT was reinterpreted as a platform for strategy definitions and enactment in virtual worlds:

- Integrated in the Potsdam Second Life platform ([Lehre in Virtuellen Welten](#))
- Applied as a 3D hands-on simulation environment of business, marketing, and communication strategies for founders of start-up companies – here mostly with a background in biology and life sciences, i.e., neither IT nor economy experts ([Science in 3D – BMBF-Projekt](#))

Further editions and variations of the computing camp in the future also include a camp for secondary school teachers, training them to use the tools in their computing classes. Dedicated OER (open educational resources) artifacts in multiple languages are going to make it easier for third parties around the world to carry out similar courses. The software, documentation, and basic tutorials are already freely available (mostly in English, partly in German). Their systematic multilingual preparation and the development of additional material, like detailed lesson plans for school teachers or video tutorials in

different languages, are ongoing. A first version was released into the Multimedia Education Resources for Learning and Online Teaching (MERLOT).

Cross-References

- ▶ [Agile Methodology in Education of IT Students, Application of](#)
- ▶ [Computational Thinking](#)
- ▶ [eXtreme Model-Driven Development \(XMDD\) Technologies as a Hands-on Approach to Software Development Without Coding](#)
- ▶ [Modeling of Scientific Workflows](#)
- ▶ [Software Development Processes Designed for First Year Computing Undergraduates](#)

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Modeling of Scientific Workflows

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Introduction

In the age of big data, scientists of all disciplines need to become data scientists to analyze increasing amounts of research data. Often the available standard software is not sufficient for specific research purposes, so that the development of own, purpose-specific software becomes necessary. Hence, computational thinking, programming, and software development skills are not only taught in computer science and closely related study programs anymore but increasingly to students of all disciplines (Marshall 2017).

Many of the software applications that (data) scientists develop for their work are however not written from scratch. Rather, they reuse existing computational components such as programming

libraries, web services, and command-line tools and combine them anew for the specific purpose. The applications hence “orchestrate” components, by defining the execution order of the components and the flow of data between them. Over the last years, the scientific community coined the term *scientific workflows* to refer to scientific software applications with these characteristics. Scientific workflows can be implemented with standard programming languages, but dedicated *scientific workflow management systems* provide specialized support that simplifies their development.

Programming scientific workflows is in fact taught in many basic programming courses for (data) scientists, although this term is mostly not explicitly used and typically no clear distinction is made from other kinds of applications. Still, the most popular languages in data science today, namely Python and GNU R, are primarily used for the implementation of data analysis scripts and pipelines, which are essentially scientific workflows. In these courses, students face two challenges at the same time: they have to learn the basics of programming in a conventional text-based language, and they have to learn how to translate a data analysis problem into a workflow that solves it. So they face at the same time programming, in a bottom-up fashion from the code level, and problem-solving task in the domain of discourse, this time top-down from a conceptual level. Research has shown that it is often more effective to teach computational thinking skills at a conceptual level separately from teaching concrete coding skills, hence the combined teaching of both skills in one course can be regarded as undesirable.

Scientific workflow management systems free workflow developers from having to deal with the technical and syntactic details of a conventional programming language. The term *modeling* is typically used for describing the process of developing scientific workflows with such systems, emphasizing that implementation-level details do not matter and that modeling is not programming. Workflow models provide a level of abstraction that allows students to focus on the workflow on a conceptual level. In most systems,

the workflow models are represented as easily readable graph structures that can be built and manipulated in interactive graphical user interfaces. This way, workflow management systems are ideally suited to teach scientific workflows independently from teaching a concrete programming language.

This entry presents and discusses three selected examples of full-term STEM courses described in recent literature that use modeling of scientific workflows as a teaching tool (Section “[Modeling of Scientific Workflows as a Teaching Tool: Examples](#)”). It then discusses their commonalities and differences with regard to the educational context in which they are used (Section “[Discussion](#)”). Section “[Conclusion and Outlook](#)” concludes the entry with a summary and perspectives for the future.

Modeling of Scientific Workflows as a Teaching Tool: Examples

Modeling scientific workflows with dedicated workflow management systems instead of implementing them with conventional programming languages focuses the attention of workflow developers on problem-solving and understanding and managing the domain-specific essentials of the workflow instead of on the technicalities of code. Consequently, scientific workflow management systems are increasingly popular among researchers of all disciplines. They are also increasingly used in computational science education to teach students how to design and validate scientific workflows independently from teaching them about programming. Not much literature is available yet on this topic, so it is still difficult to quantify and give a systematic picture of their use in educational practice. This entry reports on three examples of workflow management systems that have been used as modeling tools to teach scientific workflows, for which detailed accounts can be found in recent literature: the jABC modeling framework (Steffen et al. 2007), the VisTrails environment (Callahan et al. 2006), and the WINGS workflow system (Gil et al. 2011).

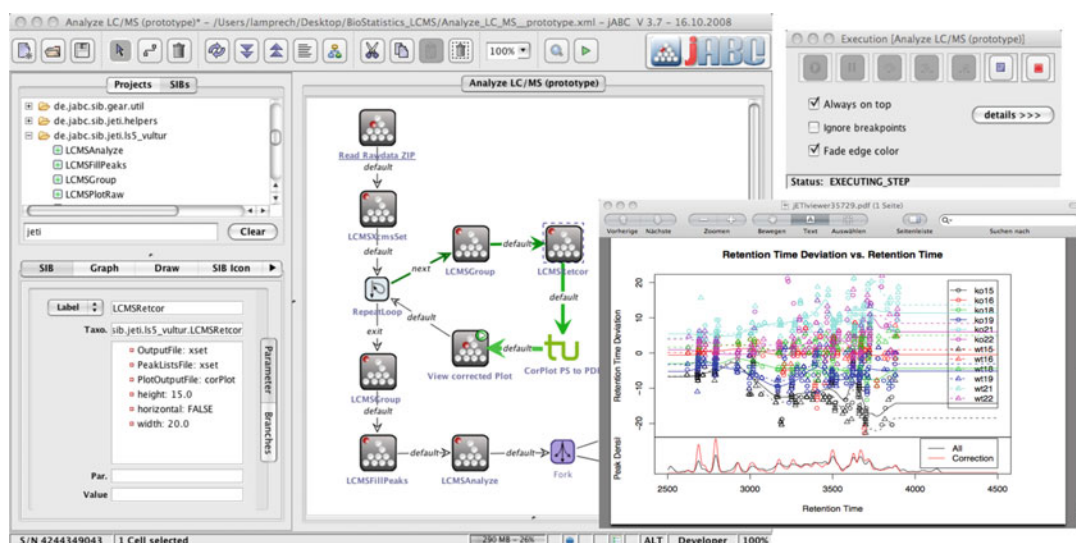
Teaching Scientific Workflows with jABC: Agility and Intuition

The Java Application Building Center (jABC) (Steffen et al. 2007) (<http://jabc.de>) is a domain-independent, multipurpose modeling framework that follows the paradigm of eXtreme Model-Driven Development (XMDD). Its predecessors date back to the mid-1990s, with the more recent releases developed by the Chair for Programming Systems at TU Dortmund University, Germany. Stemming from a context of applied formal methods, jABC has always put an emphasis on the integration of functionality for formal verification and correctness-by-construction into the application development process. The workflow models used by jABC, so-called Service Logic Graphs (SLGs), are at the same time executable control-flow graphs, as shown in Fig. 1, and also Kripke Transition Systems that can be processed by formal verification tools like model checkers. Figure 1 gives an impression of jABC's user interface during workflow execution.

From 2006 onwards, jABC has been used as a scientific workflow management system in different applications areas (Lamprecht et al. 2016), and for several years as a tool to teach scientific workflows in the scope of a “Computer Science

for Natural Scientists” course at the University of Potsdam, Germany (Lamprecht and Margaria 2014, 2015). The participants in these courses were Master students from the “Bioinformatics” and “Geoinformation and Visualization” study programs, who had little or no prior education in computer science or programming. However, they came with domain-specific knowledge from their undergraduate program and were thus able to identify relevant data analysis problems from their domains. During the course, they learned how to model executable workflows for their chosen data analysis problems with the jABC framework. Their tasks involved the definition of the overall process flow, the identification and integration of components for the individual steps, the implementation, testing, and execution of the workflow with actual data, and finally their publication accompanied by a project report. The student projects of 2012 have even been published in a collective Springer volume (Lamprecht and Margaria 2014), where they form a gallery of diverse applications of scientific workflows in education. In 2015, the course was renamed to “Process Modeling in Scientific Applications” and extended to also allow computer science students to participate. Interdisciplinary pairs

M



Modeling of Scientific Workflows, Fig. 1 jABC (version 3.7), showing a workflow for LCMS data preprocessing and analysis with the Bioconductor xcms

package (<https://bioconductor.org/packages/release/bioc/html/xcms.html>) being executed

subsequent years, also at other places, for example, at the Universities of North Carolina, USA, and Linköping, Sweden. Thirty students participated in the first edition of the course in 2007. As detailed in (Silva et al. 2011), they worked with a number of different data sets and were given six different and increasingly complex visualization assignments to be done with Vis-Trails. Instead of just the final visualization, their submissions included the complete provenance trace of their projects, enabling more comprehensive assessments of the learning process and the results.

The student reviews of the course were reported to be very positive. Lecturer observations and student feedback agreed that the simplified construction of pipelines and the detailed change-based provenance mechanism in VisTrails had a positive effect on learning about data visualization processes. They experienced a streamlined exploratory process and enhanced interactions between students, course instructors, and teaching assistants. The tree-based representation of the provenance makes it easy to jump back to previous versions, undo changes, and compare different workflows, facilitating the incremental discovery and in-depth discussion of various possible solutions. In addition to supporting the students' exploratory data analyses, it helps lecturers to develop better teaching strategies based on the observations they can make about how the students proceed and how different people might approach the same problem.

Teaching Scientific Workflows with WINGS: Semantics and Distribution

The Workflow INstance Generation and Specialization (WINGS) framework (Gil et al. 2011) (<http://www.wings-workflows.org/>) is a project lead by researchers of the Information Sciences Institute of the University of California, USA. Now a system on its own, the underlying ideas have been developed in a variety of contexts since 2003. WINGS is advertised to be a semantic workflow system, meaning that it uses semantic information about data sets and workflow

components to assist scientists to create correct and executable workflows. The workflows can be submitted to a number of different distributed execution environments.

In “Teaching Parallelism Without Programming: A Data Science Curriculum for Non-CS Students” (Gil 2014) and “Teaching Big Data Analytics Skills with Intelligent Workflow Systems” (Gil 2016), Gil et al. describe a course where WINGS workflows are used to provide students with practical experiences with parallel and distributed execution. In contrast to the way parallel computing is traditionally taught – as part of a computer science curriculum and relying on advanced programming skills – the course is deliberately targeted at nonprogrammers, assumes no programming skills and does also not aim to teach any programming. Instead, it uses WINGS workflows to teach the concepts above the level of a concrete programming language. Students can use predefined workflows and workflow components to build and test their own applications.

A pretest run of teaching the course to a small group of students is reported to have been successful. The students in the test group had no or almost no knowledge of programming, but they found the material accessible, understood the concepts, and considered them to be useful. In particular, they appreciated that the abstract concepts were supplemented with practice that did not require classical computer science skills.

Discussion

Silva et al. (2011) state in the motivation for their VisTrails course that it was driven by the intuition that “the same features that support scientists in exploratory tasks would also be beneficial to students.” The same rationale underlies also the use of jABC and WINGS for teaching scientific workflows: the same features that support scientists in working with scientific workflows will also be a powerful scaffold for students. In fact, for all the courses sketched above, it is reported that their

perceived most important asset is that the use of their particular technology allowed the students to focus on their actual tasks, instead of having to deal with technicalities and implementation details on a programming-language level. Silva et al. even conclude that they “strongly believe that teaching is one of the killer applications” (Silva et al. 2011) of workflow technology.

Table 1 examines the concepts taught and competencies trained in the three courses in more detail. They form the essential part of the intended learning outcomes of the courses. Additional soft skills (like project management or presentation techniques) exercised in the courses are not included in the table. The concepts and competencies listed in the table were collected from the

publications that describe the courses. Note that these reports do not reflect the full capabilities of the respective systems, as not all their features were used in the described teaching contexts.

Computational thinking core. Some concepts and competencies appear almost inevitably in all three courses: Students learn about general and domain-specific data types, formats, and standards, and about the principal structure of data analysis processes (pre- and postprocessing and actual analysis). More technically, they learn to apply basic control flow structures (sequential execution, conditional branching, different forms of loops to control the order of the steps in a workflow, to manage the transfer of data between the computational components (depending on the

Modeling of Scientific Workflows, Table 1 Concepts taught and competencies trained in the different courses

Concept or competence	Course jABC	Course VisTrails	Course WINGS
Data types, formats, and standards	x	x	x
Multistep data analysis (including preprocessing, analysis, postprocessing)	x	x	x
Basic control-flow structures (including conditional branching, loops)	x	x	x
Data-flow handling (shared memory, message passing)	x	x	x
Hierarchical modeling (encapsulation, sub-workflows)	x	(x)	(x)
Workflow execution and monitoring	x	x	x
Execution failures and error handling	x	x	x
Problem analysis and functional decomposition	x	(x)	(x)
Prototyping and iterative refinement	x	(x)	(x)
Discovery and integration of computational components	x		
Domain modeling (taxonomic classification of data and components)	x		
Annotation of components and workflows	x		
Workflow validation through model checking	(x)		
Synthesis of workflows	(x)		
Principles of information visualization		x	
Elementary plotting techniques		x	
Color and human perception, aesthetics		x	
2D visualization techniques		x	
Isosurfacing and volume rendering		x	
Scaling behavior of algorithms			x
Divide and conquer principle			x
Parallel computing	(x)		x
Multicore computing			x
Distributed computing (including clusters, grids, clouds, web services)	x		x
Communication among processors			x

system via a shared memory, by message passing, or both), and to organize complex workflows hierarchically making use of encapsulation and sub-workflows. They learn to execute workflows, monitor their execution, react on execution failures, and implement error handling behavior.

Agile solutions. The scientific workflow course taught with jABC let the students work on own, self-defined projects. As such, it put a particular emphasis on problem analysis and functional decomposition (students learned to analyze their problem from a computational perspective, and to identify the basic steps in the analysis and their order) and on prototyping and iterative refinement (workflows were first modelled with “dummy” components successively replaced with fully implemented and executable building blocks). Implicitly these appeared also in the other two courses, but as their focus was different, they played a less obvious role there. To implement their own projects, the students furthermore learned how to find and integrate computational components for the steps into jABC, and they were taught how to annotate and classify components and workflows in order to organize them in a systematic way. In the interdisciplinary version of the course, which was attended by computer science students as well, the students were furthermore shown how to apply the model checking and workflow synthesis features of the jABC for advanced workflow modeling support. These concepts and competencies did not play a noticeable role in the other two courses.

Visualization. The visualization course with VisTrails was naturally more focused on teaching principles of information visualization. Students used the system to practice and apply elementary plotting techniques, principles of aesthetics, 2D visualization techniques, and isosurfacing and volume rendering. Plotting of individual data sets with existing tools was also part of some of the workflows projects that were done with jABC, but the course did not actually teach concepts of information visualization.

Parallelism. The data science course with WINGS was designed to teach the principles of parallelism, which is also clearly reflected in

the table. In addition to general workflow modeling concepts and skills, students learn about complexity and run-time behavior of algorithms when executed with large sets of data and about the divide-and-conquer principle to split large complex problems into smaller, better tractable ones. The course furthermore explains and practices the principles of parallel, multicore, and distributed computing, as well as techniques for letting algorithms communicate across different processors.

Parallel and distributed computing also played a central role in the scientific workflow course taught with jABC: The workflow models support fork/join parallelism, which was indeed used by some of the students to represent naturally parallel strands of activities in their data analysis processes. More importantly, the integration of web services and other distributed resources was a key part in the students’ workflow projects with jABC. Although more generally and at a higher level of abstraction than in the WINGS-based course, principles of modern distributed computing were learned and practiced there too.

Conclusion and Outlook

Engaging STEM students with the modeling of scientific workflows has proven to be an effective teaching tool for training their competencies in dealing with computational data analysis challenges from all disciplines of science. With the ongoing further development and evolution of scientific workflow management systems, learning to program in the traditional sense might become in the future completely unnecessary for the many scientists who use algorithms and tools in flows, and do not develop algorithms and infrastructure software themselves. As evident from the three programming-free courses discussed in this entry, the skills that are needed to solve domain-specific problems are above the level of concrete programming languages. Students’ learning of the course topics benefits greatly from not having to deal with code-level technicalities.

Cross-References

- [Computational Thinking](#)
- [eXtreme Model-Driven Development \(XMDD\) Technologies as a Hands-On Approach to Software Development Without Coding](#)
- [Modeling of Games and Game Strategies](#)

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Modeling the Process of Information Technology Innovation in Education

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Synonyms

[Education](#); [Information technology](#); [Models of technological innovations](#); [Technological innovation](#)

Introduction

Change occurs in all forms of education, but particularly in relation to adoption of new information technologies. New ideas, new approaches, and new technologies frequently appear in classrooms at all levels from pre-school to university. This entry looks at the processes by which new technologies in education are adopted and used in the form they were offered, partially adopted, or rejected completely. This process is known as innovation and, rather than involving the *creation* of new technologies, describes the process of *adopting* and putting these technologies into practice (Maguire et al. 1994).

To investigate if and how new information technologies are adopted in education, it is useful to consider one of the theories of technological innovation:

- The linear model of innovation
- The diffusion of innovations
- The theory of reasoned action (TRA)
- Social cognitive theory (SCT)
- The theory of planned behavior (TPB)
- The decomposed theory of planned behavior (DTPB)
- The technology acceptance model (TAM)
- Augmented TAM (or combined TAM and TPB)

- TAM2
- The unified theory of acceptance and use of technology (UTAUT)
- Innovation translation (informed by actor-network theory)

A description of these models used in the investigation of technological innovation and adoption in education follows.

The Linear Model of Innovation: Traditional Phase Gate Model

This very early innovation model suggests that technological change occurs in a linear manner beginning with invention and moving via innovation to diffusion (Godin 2006; Wikipedia 2017) (Fig. 1).

The innovation process is seen to proceed through a series of phases arranged such that a given phase must be achieved before moving on to the next and after passing through a gate with the permission of a gatekeeper. This model is offered in two forms as either “technology push” or “market pull.” The linear model of innovation has been heavily criticized due both to its linearity and to not taking note of any feedback loops.

Diffusion of Innovations

Rogers’ (1995, 2003) theory is well known. Rogers describes diffusion of innovations as: “. . . the process by which an innovation is communicated through certain channels over time among the members of social systems. It is a special type of

communication, in that the messages are concerned with new ideas” (Rogers 1995: 5). A decision to adopt an innovation relates to the acceptance of the new idea while a decision *not* to adopt relates to the rejection.

Rogers distinguishes between two kinds of information: *software information*, which is embodied in the technology (or idea) itself, and *innovation-evaluation information*, which relates to an innovation’s expected adoption consequences (Rogers 2003). Diffusion is thus considered to be a process of information exchange by the need to reduce uncertainty and relating to a communicating social network. In the diffusion process, Rogers considers the main elements to be the following.

Characteristics of the Innovation

To explain the rate of adoption of innovations, Rogers suggests consideration of the following perceived characteristics of innovations (Rogers 2003):

- **Relative advantage** – or the degree to which an innovation is perceived as better than the idea it supersedes. Relative advantage is often expressed in terms of economic profitability, social prestige, or other similar benefits. Rogers contends that an innovation’s relative advantage is positively correlated with its rate of adoption.
- **Compatibility** – the degree to which an innovation is perceived by potential adopters as being consistent with existing values and past experiences. Compatibility with what is already in place makes the new idea seem less uncertain, more familiar, and helps to give it meaning. This is important because “the rate of adoption of a new idea is affected by the old idea that it supersedes” (Rogers 1995: 227). Rogers argues that if an innovation is perceived to be compatible with what is currently used or done, this will increase its rate of adoption.
- **Complexity** – the degree to which an innovation is perceived as difficult to understand and use. Rogers claims that the more complex the innovation, the less likely it is to be quickly adopted. In support of this conjecture, Rogers



Modeling the Process of Information Technology Innovation in Education, Fig. 1 The linear model of innovation

et al. (1980) point out that in the late 1970s, a period of 6–8 weeks of extreme frustration characterized the adoption of a new home computer!

- **Trialability** – the degree to which a particular innovation may be subjected to limited experimentation. If “playing” with the innovation is possible, adoption is more likely.
- **Observability** – the more the results of an innovation are visible to everyone, the more likely the innovation is to be adopted.

Attributes of the potential adopter, including social status and education, are also seen as important. A slightly different slant on adoption is offered by Abrahamson and Rosenkopf (1993) who describe what they call the “bandwagon effect” when people or organizations adopt innovations, not because of their technical properties, but because a large number of others have already done so.

Communications Channels

Acts of communication are a necessary part of any change process, and to reach a potential adopter, the innovation must be diffused through some communications channel (Tatnall 2005). Rogers argues that channels involving mass media are often the most rapid and efficient means of spreading awareness of an innovation, but that interpersonal channels are generally more effective in persuading someone to accept a new idea (Rogers 2003), and that interpersonal communication is more effective when it is between those who are similar in socioeconomic status and education.

Time

Innovations are not adopted instantly and Rogers suggests a five-step process involving:

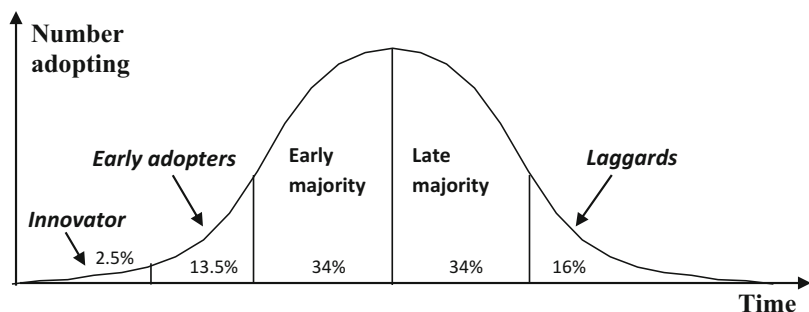
- Knowledge – when an individual is exposed to an innovation’s existence
- Persuasion – the formation of a favorable or unfavorable impression
- Decision – an action that leads to adoption or rejection
- Implementation – the innovation is put into use
- Confirmation – seeking reinforcement of an innovation-decision. “Have I made the right decision?”

He then classifies people in terms of innovativeness as belonging to one of the following groups: innovators, early adopters, early majority, late majority, and laggards (Fig. 2).

The Social System

Diffusion is seen to occur within a social system where the social structure constitutes a boundary inside which the innovation diffuses. Rogers argues that the system’s social structure affects diffusion through the action of social norms, the roles taken by opinion leaders and change agents, the types of innovation decisions that are taken, and the social consequences of the innovation (Tatnall 2005). “*Technology is a product of society, and is influenced by the norms and values of the social system*” (Rogers 1995: 139). Innovation Diffusion thus accepts concepts from the social construction of technology, and is based on the idea that technology is shaped by social factors.

Modeling the Process of Information Technology Innovation in Education,
Fig. 2 Categories of adopters. (Adapted from Rogers 1995: 262)



The Theory of Reasoned Action (TRA)

Fishbein and Ajzen (1975) developed the theory of reasoned action in 1975, before later comprehensively refining it with empirical evidence to support its validity and reliability (Ajzen and Fishbein 1980). In developing this theory, they made use of various studies on attitude from social psychology in order to develop an integrated conceptual framework to predict and explain an individual's behavior in a general setting. They postulated that beliefs influence attitude and social norms which in turn shape a behavioral intention guiding or even dictating an individual's behavior. They focused on three major determinants of an individual's behavior: behavioral intention, attitude, and subjective norm. In summary, they postulated that:

- An individual's behavioral intention is the immediate determinant of behavior.
- Attitude and subjective norm are mediated through behavioral intention.
- Behavioral and normative beliefs are mediated through attitude and subjective norm, respectively.

Although TRA gained wide acceptance in the behavioral sciences, the likelihood that a person will actually perform the specific behavior described has been questioned by many researchers (including: Warshaw and Davis (1985) and Davis et al. (1989)). In a situation where there is a gap between behavioral intention and actual behavior, some studies have found a low correlation between these two (Bonfield 1974; Harrell and Bennett 1974).

Social Cognitive Theory (SCT)

Developed by Bandura (1986), SCT suggests that human functioning should be viewed as the product of a dynamic interplay of personal, behavior, and environmental influences. He argued that how people interpret the results of their own behavior informs and alters their environments and the

personal factors they possess which, in turn, inform and alter subsequent behavior. Social cognitive theory gives consideration to:

- Personal factors (cognition, affect, and biological events)
- Behavior
- Environmental influences

The Theory of Planned Behavior (TPB)

TPB was developed by Ajzen (1985, 1991) after the identification of problems with the theory of reasoned action. Ajzen's main criticisms of TRA were that it was designed to predict and explain behavior, or actions, based on the assumption that the behavior was under a person's own control. But as some behavior is directed by outside influences and is not under a person's own control, there might be problems due to the differences in other individuals' abilities and in external forces, and this may influence actual performance of the behavior. He argued that consideration should be given to the concept of behavioral control to overcome these volitional control problems. To achieve this, Ajzen extended TRA by the addition of another construct called *perceived behavioral control*. This refers to an individual's perception of the "... presence or absence of requisite resources and opportunities" (Ajzen and Madden 1986:457) required to perform the specific behavior.

Following TRA, the theory of planned behavior assumes that behavioral intention is a function of two determinants: the individual's attitude toward the behavior and the subjective norm within the social environment. Ajzen (1991) argues that the addition of perceived behavioral control is important as it is expected that this concept will illustrate the likelihood of success in performing the behavior, and it is expected that it will provide a measure of actual control. Its validity as a measure to predict the likelihood of achieving the target behavior will depend on the individual's capability (e.g., having the requisite opportunities and resources) to exercise

control over the specific behavior. This means that a person who believes that they have the resources and opportunities expects fewer problems in performing the specific behavior and hence perceives that they have complete control over the specific behavior.

The Decomposed Theory of Planned Behavior (DTPB)

DTPB, introduced in 1995 by Taylor and Todd (1995a, b) suggests that behavioral intention is the primary direct determinant of behavior, but that attitude toward behavior, subjective norm, and perceived behavior control are also important. They suggest decomposing attitudinal belief into three factors: perceived usefulness, perceived ease of use, and compatibility.

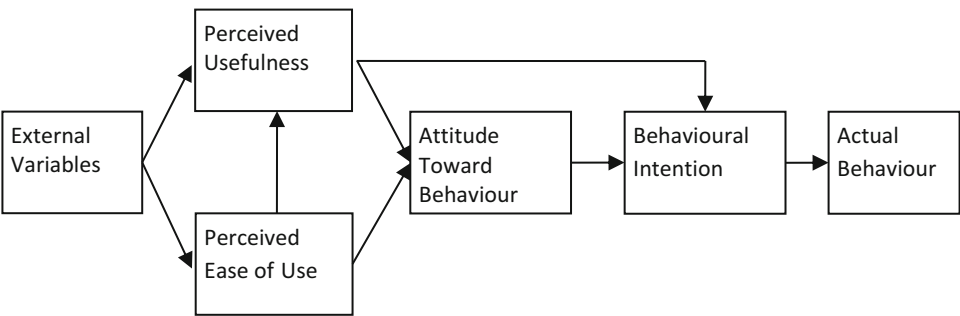
The Technology Acceptance Model (TAM)

The technology acceptance model was developed from TRA by Davis and his colleagues (Davis 1986, 1989; Davis et al. 1989; Davis and Venkatesh 2004). TAM assumes that a computer user normally acts rationally and uses information in a systematic manner to decide whether or not to adopt this particular technology in the workplace. Davis (1986) identifies major determinants of technology acceptance and specifies a basis for causal links between the technology’s *perceived*

usefulness and *perceived ease of use* along with the individual’s *attitude toward using technology* and *behavioral intention* to explain technology adoption (Davis 1986, 1989; Davis et al. 1989) (Fig. 3).

In TAM, the effects of external variables (including system characteristics, development processes, education, or training) on the intention to get someone to use the technology are mediated by *perceived usefulness* and *perceived ease of use*. TAM has strong behavioral elements which assume that someone using a computer acts rationally and uses any available information systematically in order to decide whether or not to adopt this technology. TAM assumes that when someone forms an *intention* to act, they will be free to act without any limits, and that they will do so. Perceived usefulness is influenced by perceived ease of use because if other things are equal, the easier the new technology is to use, the more useful it must be (Venkatesh and Davis 2000). TAM assumes that adoption and use of any new information technology is voluntary (Davis 1989), and that provided they have sufficient time and knowledge about the technology, their stated preference to perform the activity and their behavioral intention will determine the way in which they behave and how they will adopt the technology (Tatnall 2011).

TAM offers a theoretical basis for specifying the linkages between perceived usefulness and perceived ease of use in determining users’ attitudes, intentions, and actual information systems adoption behavior. Behavioral intention is jointly



Modeling the Process of Information Technology Innovation in Education, Fig. 3 The technology acceptance model (Davis 1986, 1989)

determined by attitude and perceived usefulness, while attitude is determined by perceived usefulness and perceived ease of use.

Augmented TAM (or Combined TAM and TPB)

TAM does not include the influence of social and control factors on behavior but those factors have been found by Taylor and Todd (1995a, b) and Moore and Benbasat (1991) and others, to significantly influence technology usage behavior. Taylor and Todd (1995a) developed augmented TAM by the addition of two factors to TAM: subjective norm and perceived behavioral control to provide what they saw as a more complete test of the important determinants of technology usage because of their predictive and wide use in social psychology (Kripanont 2007).

TAM2

Venkatesh and Davis (2000) developed TAM2 as a theoretical extension of TAM to include additional key determinants that explain perceived usefulness and usage intentions in terms of social influence and cognitive instrumental processes, and to understand how the effects of these determinants change with increasing user experience over time with the target system.

The Unified Theory of Acceptance and Use of Technology (UTAUT)

UTAUT was developed by Venkatesh et al. (2003) to provide a refined view of how the determinants of intention and behavior evolve over time in explaining IT usage behavior. UTUAT was developed from the theory of reasoned action, the technology acceptance model, motivational model, the theory of planned behavior, a combined theory of planned behavior/technology acceptance model, the model of personal computer use, diffusion of innovations theory, and social cognitive theory (Venkatesh et al. 2003). UTAUT offers

behavioral intention and usage behavior as two dependent variables in the model. It introduced four core determinants of intention and usage:

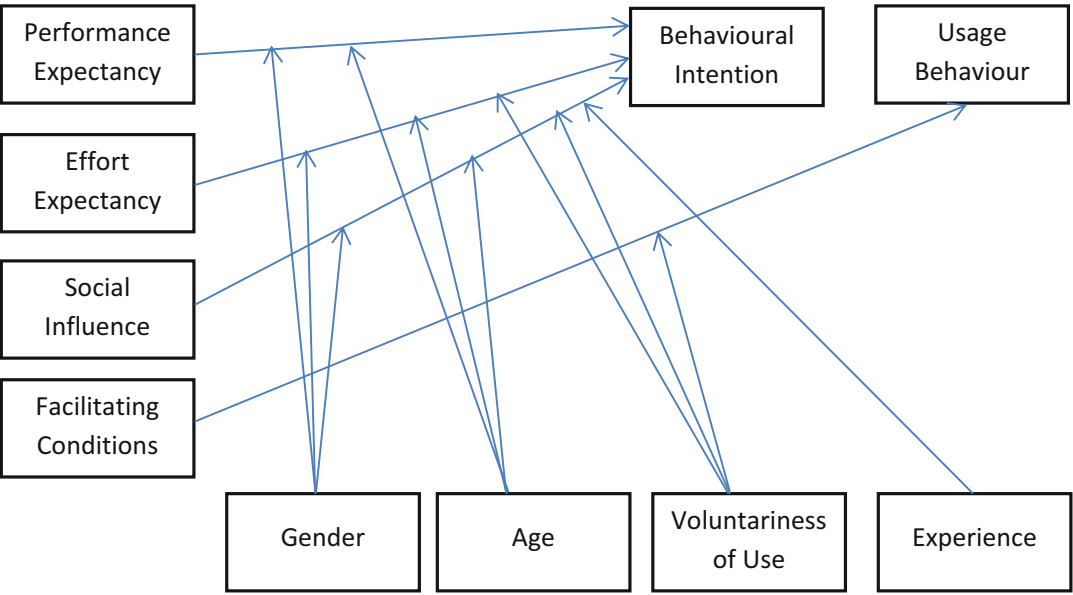
- Performance expectancy
- Effort expectancy
- Social influence
- Facilitating conditions (Fig. 4)

Attitude toward using technology, self-efficacy, and anxiety are theorized *not* to be direct determinants of intention to adopt and use. The key moderators identified in the model are gender, age, voluntariness, and experience (Kripanont 2007).

Innovation Translation (Informed by Actor-Network Theory)

A common approach to researching innovation in information systems is to focus on the technical aspects of an innovation, and to treat “the social” as the context in which its development and adoption take place (Tatnall 2007). The view of innovation proposed by actor-network theory (ANT), sometimes known as sociology of translations (Callon 1986b; Latour 1986, 1996; Law 1987), considers the world to be full of hybrid entities containing both human and nonhuman elements, and offers the notion of heterogeneity to help in the explanation of technology adoption (Tatnall and Davey 2003). Innovation translation (Callon 1986b; Latour 1996), informed by ANT, makes use of a model of technological innovation which uses ANT concepts, as well as the concept that innovations are often not adopted in their entirety but only after “translation” into a form that is more appropriate for use by the potential adopter.

In actor-network theory, the extent of a network is determined by actors that are able to make their presence *individually felt* (Law 1987) by other actors. Each actor is not just a “point object” but an association of heterogeneous elements, making up a network. An actor can, however, also be considered as a “black box” (Callon 1986a), containing other actors that we may not, at the moment, want to see or deal with. When we open the lid of the box to look inside, a whole



Modeling the Process of Information Technology Innovation in Education, Fig. 4 The unified theory of acceptance and use of technology (Venkatesh et al. 2003)

network of other, perhaps complex, actors and associations will appear. The value of the black box concept is that in many cases details of what constitutes an actor – details of its own network – are a complication we can avoid having to deal with at this time.

Callon (1986b) proposes that translation involves strategies through which an actor identifies other actors and places them appropriately in relation to each other. Latour (1996) speaks of how “chains of translation” can transform a global problem, such as the transportation needs of a city like Paris (or a new approach to obtaining appropriate software for the educational curriculum), into a local problem like continuous transportation (or how to introduce the concept of programming to Grade 3 students).

Latour (1996) suggests that with an innovation translation model, the initial idea counts for little, and unlike some of the other innovation theories, the innovation itself is not endowed with “autonomous power” or “propelled by a brilliant inventor,” but only moves if it is of interest to one group of actors or another (Tatnall 2009). Movement of the innovation is a consequence of energy given to it by everyone in the chain and when the

innovation does interest a new group, they transform it a little or perhaps a lot (Latour 1996: 119). Latour (1986) maintains that in the innovation translation model the movement of an innovation through time and space is in the hands of people, each of whom may react to it in different ways: they may modify it, deflect it, betray it, add to it, appropriate it, or let it drop. Here, instead of a process of transmission, we have a process of continuous transformation (Latour 1996) where faithful acceptance involving no changes is a rarity. “Instead of the transmission of the same token – simply deflected or slowed down by friction – you get ... the continuous transformation of the token” (Latour 1986: 286). Latour notes that, except in rare cases, there can be “no transportation without transformation,” and that “... after many recruitments, displacements and transformations, the project, having become real, then manifests, perhaps, the characteristics of perfection, profitability, beauty, and efficiency that the diffusion model located in the starting point” (Latour 1996: 119).

Suppose that some new technology has been developed and some person, group, or organization would like to get it adopted. Actor-network

theory asserts that the contributions of both humans and nonhumans (information technology in this case) need to be given equal consideration, so this person or group proposing the new technology is referred to by the term heterogeneous engineer. In explaining how this process works, Callon (1986b) outlines four aspects or “moments” in the process of translation:

1. *Problematization* involves the heterogeneous engineer defining the nature of the problem so as to be seen by other actors as having the answer.
2. *Interessement* involves interesting and attracting an entity by coming between it and some other opposing entity.
3. *Enrolment* occurs through a process of “coercion, seduction, or consent” and, if all goes well, leads to the establishment of a solid, stable network of alliances.
4. *Mobilization* locks in as the solution proposed by the heterogeneous engineer gains wider acceptance through some actors working to convince others.

Conclusion

In the case of adoption of new IT in education, which model is the most appropriate? This depends on the scale, complexity, and nature of the situation under consideration. Of the models that could be used in an investigation of information technology innovation and adoption, only three are now in serious use: innovation diffusion, UTAUT (incorporating TAM and several of the others), and innovation translation.

Innovation diffusion, as the name suggests, is useful for examining the large-scale spread, or diffusion, of innovations around a large area. When studying the international uptake of mobile phones, diffusion offers a useful approach. In education, the diffusion of the teaching of coding (programming) in schools is another situation where this approach would be useful.

The unified theory of acceptance and use of technology (UTAUT) is used mainly to examine the uptake of IT by businesses and other large

organizations. It assumes that the potential adopter has free choice in making the decision on whether or not to adopt, and concentrates on analysis of the human properties and actions involved.

Actor-network theory (ANT) considers the role of both humans and the technology (nonhumans) in the potential adoption. Innovation translation places equal importance on each and suggests that innovations are not adopted as is, but are first translated into a form suitable to the potential human adopter. For many situations in educational use of information technology where both people and the technology itself have an important role to play in the adoption, innovation translation offers a useful approach.

Cross-References

- [Technological Innovation in ICT for Education](#)

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MOOCs, Teacher Professional Learning and Deep Learning Conversations

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This entry describes an innovative model of teacher professional learning that has evolved over a decade (2006 to 2016). In particular, it explores how this face-to-face model of professional learning can be successfully reconfigured in an online environment to help scale up the initiative. Designed as a school-focused, job-embedded teacher professional learning framework that meets teachers' expressed needs, the model helps to shift teachers' pedagogical orientations and challenge more traditional instructional environments by embedding digital technologies and other elements of twenty-first-century skills into the teaching and learning experience. Building on the experiences of implementing this framework, this entry reports the most recent phase which attempts to harness the emergence of a 4th wave of online learning. This initiative involves the design and development of a Massive Open Online Course (MOOC) that potentially enables the massive scaling up of access to this already validated model of teacher professional learning. The importance of maintaining key elements, threshold concepts, and signature pedagogies in the design of MOOCs for teacher professional learning is discussed. The entry also explores some of the challenges and potential opportunities different MOOC delivery models offer for sustaining the types of collaboration, rich dialogue, and ongoing reflection observed in earlier phases of the project.

Introduction

Stated goals for the development of “21st century skills” include critical thinking and problem-solving, communication, collaboration, self-regulation, information management, and the ability to use digital technology effectively and reflectively (e.g., ETA 2010; OECD 2005; Binkley et al. 2012) and have become commonplace globally. There is growing consensus that both teaching methods and learning environments need to change to help students develop the skills they need to succeed in the twenty-first century (e.g., Ananiadou and Claro 2009). Despite this, past experience suggests teachers rarely have access to specific guidance or sufficient support on how to design learning scenarios which develops these skills in the classroom. Faced with this reality, the challenge is how to design professional learning experiences for teachers that enable them, in turn, to design learning activities so that their students can develop the dispositions, skills, and competencies that are required to live and thrive in this complex, globally connected world of the twenty-first century.

Against this backdrop, this entry describes an innovative model of teacher professional learning that evolved over a decade (2006 to 2017). It begins by describing the professional learning model for teachers which was designed and developed in a single secondary school in Ireland before being expanded district wide. The impact of this job-embedded program is outlined indicating the shift in pedagogical orientation and the resulting student learning. It then explores how this face-to-face model of professional learning can be successfully reconfigured in an online environment to help scale up the initiative while also being mindful of the importance of maintaining key elements, threshold concepts, and signature pedagogies in the design and development of the scalable model.

Background and Context: Teacher Professional Learning Model

Originating in Microsoft's “Innovative Schools Program” (ISP), the focus of the initiative was

the integration of digital technologies into teaching and learning in the postprimary sector, and the main objective was to design a model for teacher professional learning in a large Irish secondary school. This approach was considered particularly important in Ireland because rigid state standards and a traditional exam-based system of education at secondary level constrain teachers' ability to change their instructional practices. It leaves them with little time or flexibility to introduce new ideas or practices.

In developing a model for teacher professional learning, the lead authors (Butler & Leahy) realized the need not only to work closely with teachers and school management but also the importance of focusing on the teachers' beliefs and values as the starting point. This focus was based on research evidence that teachers' pedagogical orientations are a dominant factor in how they choose to use (or not) new technology in their classroom (e.g., Law and Chow 2008; Shear et al. 2011; Lawrence and Tar 2018). It follows from this line of research that professional learning programs are most effective when they are:

- (i) Embedded into teachers' professional lives and communities within the school (National Foundation for the Improvement of Education 1996)
- (ii) Focused explicitly on local goals for student learning (e.g., Darling-Hammond 1993)
- (iii) Grounded in collective discussions of classroom practice (Warren Little 2003)
- (iv) Anchored in active learning supporting collaboration and critical reflection over a sustained duration (Darling-Hammond et al. 2017).

Previous experience in developing a model of professional learning had also led to the realization that in order to change classroom practice, teachers need to ask questions about their existing classroom practices (Butler 2004). To this end, key features of the professional learning program were that it was directly related to the teachers' stated needs and experiences, anchored in the meaningful context of their own classroom practices and in particular, teachers were challenged to question their practice. The Learning Activity/Student Work (LASW) framework (see Table 1) developed by Stanford Research Institute (Shear et al. 2009) was used as a key feature of the professional development program developed as part of the ISP program in Ireland.

The framework was the catalyst that enabled the teachers to design learning activities in which they embedded twenty-first-century learning principles, develop the meta-language used to

MOOCs, Teacher Professional Learning and Deep Learning Conversations, Table 1 Learning Activity/Student Work (LASW) dimensions

Learning activity dimensions	Student activity dimensions
Collaboration: Are students required to share responsibility and make substantive decisions with other people?	Collaboration: Did the student share responsibility? Did the student make substantive decisions with other people?
Knowledge building: Are students required to build knowledge? Is that knowledge interdisciplinary?	Knowledge building: Did the student build knowledge? Was that knowledge conceptually accurate and interdisciplinary?
Use of ICT for learning: Do students use ICT to support knowledge building? Is ICT necessary to that knowledge building?	Use of ICT for learning: Were students passive consumers, active users, or designers of ICT?
Self-regulation: Is the learning activity long-term? Do students plan and assess their own work?	Skilled communication: Did the student produce extended communication? Was the communication well-developed and organized around a thesis?
Real-world problem-solving and innovation: Does the learning activity require solving authentic, real-world problems? Are students' solutions implemented in the real world?	Real-world problem-solving and innovation: Did the student develop a successful solution to a real-world problem? Did the student implement the solution in the real world?

describe such learning environments, as well as reflect on their teaching and the assignments they set their students (Butler and Leahy 2010, 2011, 2015). The professional development program was directly linked to a university postgraduate accreditation process.

Building on the success of Phase 1, the initiative was expanded to district level in Phase 2. In consultation with Butler and Leahy, management decided to invest funding into the professional learning of a key group of teachers in schools across the district. It was perceived that these teachers would become peer coaches and promote the creative integration and use of digital technologies in teaching and learning among teachers at their schools. The target group identified to become peer coaches were the ICT coordinators from schools across the district. Traditionally, the role of ICT coordinator was associated with ensuring that hardware was in working order or at best supporting the development of teachers' technical ICT skills. However, this role was redefined whereby ICT coordinators were now expected to support innovative and emerging new pedagogies and technologies to facilitate student learning and the development of twenty-first-century skills. The management also requested that formal accreditation would continue to be a feature of the program. In response, the Digital Learning Peer Coaching (DLPC) program was developed (c.f. Butler and Leahy 2015).

Impact of the Professional Learning Model

Across Phases 1 and 2, teachers, school leaders, and management initially tended to view digital technologies as tools to support traditional practices. However, through active participation in the program, their understanding shifted, and they began to perceive new technologies as tools that facilitate more progressive classroom practices and the development of their students' twenty-first-century skills. Evidence of this change and enhanced quality of education are found in the national evaluation reports of the ISP as well as through analysis of the coursework and final dissertations produced by teachers participating in the postgraduate diploma (Butler

and Leahy 2015). Together, they demonstrate that the overriding impact of the program was to move teachers "out of their comfort zones" (Butler and Leahy 2015). It enabled the participating teachers to design learning environments which were more student-led and characterized by the use of a range of digital technologies supporting an enquiry process that demanded the use of essential skills such as knowledge construction, problem-solving and innovation, self-regulation, skilled communication, and collaboration. This was evident by the emergence of the following trends in classroom practices:

- Student-centered learning
- Project-based learning rather than discrete lesson plans
- Students working collaboratively in groups rather than individual learning
- Focus on learning not on subject "content"
- Awareness of designing lessons with opportunities for students to develop twenty-first-century skills
- Increase in teacher confidence to use a greater range of pedagogical strategies/digital technologies
- Collaboration across and between subject departments (i.e., ripple effect)

The shift in pedagogical orientation along with increased use of digital technologies in learning and teaching had a positive impact on student learning, resulting in learners:

- Taking more control of their own learning
- Having greater ownership of the learning activities
- Demonstrating more engagement/participation
- Increased collaboration
- Being active rather than passive in their learning
- Taking on new leadership roles

The Issue of Scalability

Although the developments and findings outlined above were encouraging, the issue of scalability has become increasingly problematic. Policy decisions in relation to the development of

a range of “21st century skills” (NCCA 2009), as well as the ability and the need to use digital technology effectively and reflectively in schools in Ireland, led to ongoing demands to extend this model of professional learning. In particular, the launch of the Digital Strategy (DES 2015) in Ireland identified “a need to ensure that ALL teachers are equipped with the knowledge, skills and confidence to integrate ICT into their practice” (p. 7). As a way of addressing the issue of scalability, the possibility of using an innovative MOOC format was considered in the wider context of the emergence of a 4th wave of online learning (Picciano 2014) which builds on the principles and foundations of blended learning.

MOOCs as a Possibility of Scaling the Model of Professional Learning

Research literature suggests that MOOCs have been most successful for those who already hold an undergraduate college degree or higher (e.g., Ebben and Murphy 2014). While MOOC completion rates are low, prior level of schooling is a predictor of achievement in MOOCs (Greene et al. 2015), thus suggesting that teachers completing a MOOC for professional learning might be more likely to complete it than other participants (Hodges et al. 2016). In fact, Laurillard (2016) considers the use of a MOOC as a medium for the continuing professional learning of teachers as “a perfect fit” (p. 7). Misra (2018) supports this view and argues that MOOCs “can be a cost and resource effective means to complement the traditional methods of professional development of teachers” (p. 67). Therefore, coupled with the growing number of open solutions targeting schools (e.g., ICEF Monitor 2016; Vivian et al. 2014), it was a logical step to investigate the use of a MOOC to scale the model of teacher professional learning that had been developed.

The Many Guises of a MOOC

MOOCs are now recognized as a valid form of professional learning in a number of professions. For example, in 2014 in Ireland, the Law Society

became the first professional body to successfully implement a MOOC with over 2000 participants as part of a formal professional learning program. Since then, MOOCs have demonstrated their potential to attract large numbers of learners, particularly highly qualified professionals to participate in free education programs (Laurillard 2016). Moreover, there are now several accreditation pathways available through MOOCs, and there is a more sophisticated understanding of the issue of completion rates from a learners’ perspective (Henderikx et al. 2017).

MOOCs can be defined as “typically involving structured and sequenced teacher-led activities (e.g. videos, readings, problem-sets) coupled with online assessments and usually some venue for student interactions such as a discussion forum” (Greene et al. 2015, p. 927). This typical and dominant form of a MOOC is usually described as an xMOOC (Downes 2012). In contrast, MOOCs which emphasize connecting with learners through blogs and forums rather than on structured resources are referred to as cMOOCs (McGreal et al. 2013 in Jobe et al. 2014). They are designed so that learners can learn “through practice (construction and responding to feedback), discussion (comments and conversations) and production (negotiating an output for evaluation by others), making it a complex and valuable learning process” (Laurillard 2016, p. 16). The challenge in the tradition of a cMOOC is therefore to design learning experiences that support large numbers of teachers to engage in a model of co-learning, which, as stated by Avalos (2011), involves:

networking and interchanges among schools and situations and is strengthened in formalised experiences such as courses and workshops that introduce peer coaching or support collaboration and joint projects ...the lesson learned is that teachers naturally talk to each other, and that such talk can take on an educational purpose. (cited in Laurillard 2016, p. 3)

Implicit in this statement and arguably the most important requirement is to design and enable opportunities for large numbers of teachers to talk purposefully to one another online. The challenge was how to do this.

Can Deep Learning Conversations Be Recreated Live Online?

Much of the study of interaction in online and distance education contexts has to date focused on asynchronous communication, such as forums (written discussions) (e.g., Blanchette 2011). This body of research has found that asynchronous is valuable for considered discussion, where people have time to reflect and then respond. Except for an Australian study which produced a handbook on the potential of blended synchronous learning (Bower et al. 2014), there is relatively little research conducted on synchronous oral discussions. For example, a recent systematic review of two decades (1995–2014) of research on synchronous online learning found no research articles published before the year 2000, although the work did identify over 150 publications since this date (Martin et al. 2018). Nevertheless, the question if deep discussions can be facilitated using synchronous online learning tools is still an emerging area in the literature. What is known is that, all too often, such live sessions have been found to be overly teacher directed (Hallissy 2014) and lacking in meaningful interaction between the tutor and learners and between learners.

Recent technological advancements can support many activities which have the capability to enhance discussion. These include document sharing, editing, LiveChat, and online polls. Nevertheless, there is still uncertainty if or how these tools can most effectively facilitate deep discussion and if there is a need for additional technologies to enable the “recreation” of the live classroom/learning space online. What is known is that *interaction* is essential to meaningful online learning (Abrami et al. 2011, p. 1246) where interaction is defined by Bannan-Ritland (2002) as a:

two-way communication among two or more people within a learning context, with the purposes either task/instructional completion or social relationship-building, that includes a means for teacher and learner to receive feedback and for adaptation to occur based upon information and activities with which the participants are engaged. (p. 6)

At the same time, there is also the need to be mindful that frequency of interaction does not

equate to quality (Northup 2001 as cited in Hirumi 2002). Not surprisingly, the tutor is key in recreating deep conversations in synchronous online environments. Issues such as the leadership role of the tutor as well as their pedagogical beliefs and disposition must also be taken into account. Laurillard (2002) and Garrison and Cleveland-Innes (2005) place a high value on the leadership role of the tutor in “triggering” discussion and “structuring” to sustain interactions. While the affordances of synchronous online learning tools do matter, knowledge of how to construct and lead discussion using these tools is paramount toward promoting meaningful interaction. The critical factor is that the interaction promoted is a dialogue, i.e., a two-way exchange, where learners are provided with feedback in order to take action (Laurillard 2002). It is through this type of iterative process that learners are believed to deepen their knowledge. Such interactions rely heavily on the skill and competence of the tutor to design quality discussions (Blanchette 2011).

The pedagogical beliefs of the tutor are equally important. Being conversant with the online learning tool technology and comfortable in leading discussion does not ensure that deep discussion will be engaged in by all participants. Rather, Brookfield and Preskill (2005) suggest that if the tutor’s pedagogical beliefs support the design and implementation of social constructivist learning theories, then learners are more likely to engage in deep discussion “live” online; they contend:

Taking discussion seriously moves the centre of power away from the teacher and displaces it in continuously shifting ways among group members. It parallels how we think a democratic system should work in the wider society. In this sense, classroom discussions always have a democratic dimension. (pp. xvii–xviii)

Thus, from this perspective, discussion moves the power away from the tutor toward the creation of a more democratic model of learning where the learners take ownership for their learning. By engaging in this type of discussion, participants stay focused on the topic, offer evidence to support their point of view (or explain the basis for that view), recall and summarize some of the multiple viewpoints that have been shared,

attempt to identify connections between contributions already made, and show how the discussion has changed their thinking or added to their knowledge. In short, they are able to contribute to the creation of new knowledge (Brookfield and Preskill 2005).

In order to design and maintain such critical discussions with their learners, Brookfield and Preskill have identified the following nine dispositions that tutors need to develop (see Table 2). They note that both increasing understanding and resolving conflict are underlying principles of this pedagogy of discussion.

Brookfield and Preskill assert that by developing such dispositions, tutors will be able to engage in intense debate and dialogue. It suggests that the responsibility lies with the tutor to create democratic and challenging environments where they and their learners can engage in deep knowledge construction (Balaji and Chakrabarti 2010). They, as tutor and instructional leader, must inevitably cultivate a presence in such spaces (Stavredes 2011), and their own teaching beliefs and

perspectives will undoubtedly influence this. However, such a role demands high levels of expertise on the part of the tutor who must also be aware of a potential power relationship. It is all too easy for tutors to slip back into using didactic transmission, so they need to be mindful of this. To promote student growth, tutors need to ensure that learners have opportunities to share their views and to engage in discussions. It is also essential that tutors focus on learning to listen and to hear others so that they can use strategies such as questioning, criticism, discussion, and deliberation effectively (Brookfield and Preskill 2005; Bower et al. 2014). In this way, the tutor has a critical role to play in structuring and “scaffolding” the types of interactions that take place online (e.g., Rovai 2004). (The notion of scaffolding is very much associated with the work of Vygotsky (1980) and with a social constructivist view of learning.)

Yet the learner too has a key role to play in such settings as they need to take responsibility for their own learning and engage constructively

MOOCs, Teacher Professional Learning and Deep Learning Conversations, Table 2 Nine discussion dispositions in Brookfield and Preskill (2005)

Disposition	Brief description
<i>Hospitality</i>	The tutor creates an atmosphere where learners feel welcome and secure and one where there is humor
<i>Participation</i>	To maximize participations, tutors must create a democratic classroom where everyone is encouraged to participate and where it is acceptable to remain silent, if so desired. Tutor's role is to manage the discussion and draw students in
<i>Mindfulness</i>	Entails “losing ourselves” by becoming completely absorbed in what somebody else has to say. It involves learning to listen and to hear others and may even involve tutors modeling this behavior for learners
<i>Humility</i>	A willingness to admit that one's knowledge and experience are limited and incomplete and to act accordingly
<i>Mutuality</i>	The notion that our flourishing is contingent on the flourishing of others and this commitment to helping others and working with others leads to trust. It is designed to create a safe place where learners can be open
<i>Deliberation</i>	Refers “to the willingness of participants to discuss issues as fully as possible by offering arguments and counterarguments that are supported by evidence, data, and logic and by holding strongly to these unless there are good reasons to do so” (p. 13). This allows all to engage in robust debate where all views are valued. They note such a disposition takes a long time to create
<i>Appreciation</i>	Bringing people together as few of us take enough opportunities in everyday life to express appreciation to one another for a thoughtful comment, a powerful insight, etc.
<i>Hope</i>	This “provides us with a sense that all of the time, effort, and work will benefit us in the long run, even if only in a small way” (p. 16)
<i>Autonomy</i>	“If democratic classrooms seek to promote individual and collective growth, then people who retain the courage, strength, and resolve to hold on to an opinion not widely shared by others should be given their due” (p. 17)

with the tutor and their peers (Anderson and Garrison 1998). Learners can sometimes become frustrated with discussion viewing it as a waste of their time (Brookfield and Preskill 2005).

While other learners may be considered “lurkers” (Salmon 2000) having “low” or “no visibility” resulting in “silence” online, particularly in synchronous discussions when students are not actively participating, Gulati (2004) notes that:

In some formal online learning discussion, the choice of safety through silence may not be an option. The formality of online practices that aim to promote openness and democratic learning seemed to have ignored the need to feel, free, confident and secure to choose to participate openly or learn silently. (p. 8)

Thus, tutors need to be aware that student silence may be an indication of other feelings such as a lack of confidence or trust to share a view or an opinion. It is at times like this that tutors need to consider how they can create a democratic classroom where everyone is encouraged to participate and where it is acceptable to remain silent. This type of democratic participation is encapsulated in a teacher education context in the Fully Online Learning Community (FOLC) model described by Blayone et al. (2017) that builds on the Community of Inquiry (COI) model, which underpins contemporary approaches to the design of distance education, including MOOCs. This model also underscores the importance of teacher presence coupled with rich and meaningful interactions as the basis of deep learning.

In summary, the literature on synchronous online learning suggests that the role of the tutor in designing and enabling meaningful interactions and discussion is essential. It also suggests that their pedagogical beliefs and their technical knowledge of the online technologies are key to ensuring deep discussions. However, there is limited evidence that synchronous online learning tools, on their own, without skillful facilitation and intervention by tutors can recreate welcome and safe places for learners to engage in open deliberation.

21CLD MOOC: Design and Development

To address the identified gap in the literature regarding synchronous online learning, and the potential of MOOCs as a means of scaling the model of teacher professional learning, funding was secured from Microsoft to design an online course. Working with a partner in the education sector (H2 Learning), the intention was to develop a MOOC that would challenge and enable teachers to examine and change their own classroom practices, as they relate to innovative uses of digital technologies to support their own and their students’ learning and the development of twenty-first-century skills (Fig. 1).

In keeping with Phases 1 and 2 of the teacher professional learning framework, a central feature underpinning the MOOC design was the tenet that it is teachers’ understanding of twenty-first-century skill requirements that influence the ways



MOOCs, Teacher Professional Learning and Deep Learning Conversations, Fig. 1 Phased development of the model of teacher professional learning

in which they use ICT (e.g., Law and Chow 2008). As previously established, when teachers' pedagogical orientations are underpinned by understandings of twenty-first-century learning, they take on a more facilitative role, provide student-centered guidance and feedback, and engage more frequently in exploratory and team-building activities with students. Findings in Phases 1 and 2 (Butler and Leahy 2015) were that change in teachers' pedagogical orientation and the emergence of a culture of self-evaluation was directly attributed to the use of the Learning Activity/Student Work (LASW) framework and the deep discussions they engaged in around their classroom practice. To this end, rooted in the LASW framework (now called 21st century learning design, which has been shortened to be known as 21CLD), an eight-module, self-directed course was designed and developed over a period of 9 months as a core component of the MOOC design. The modules explore what learning looks like in the twenty-first century and how innovative teaching practices can support student learning to develop the key twenty-first-century skills of collaboration, knowledge construction, self-regulation, problem-solving and innovation, skilled communication, and the use of ICT for learning. As well as defining, explaining, and illustrating each of the skills, an integral part of each module is an "in-action" video in which teachers from across the world showcase how they have embedded a specific skill in their classroom. Thirteen teachers from countries such as Finland, Canada, South Africa, and Australia designed these extended learning units for their students which focus on the development of twenty-first-century skills (e.g., collaboration, knowledge construction, etc.) while also embedding the use of a range of digital technologies. The teachers were selected from the global cohort of Microsoft "Teacher Fellows" who understood the LASW framework. The teachers were supported by the design team (lead authors and H2) as they developed and implemented the learning units in their classrooms. Mentoring and feedback was provided individually to the teachers through email and Skype. In addition, regular online meetings were also held with all teachers

and the design team. Over a 3-month period, the teachers captured and documented learning processes and evidence of specific skills using handheld video cameras and uploaded their raw footage to a dedicated online space which was only accessible by the design team. Working with this footage, the design team then constructed a comprehensive "in-action" video for each of the key twenty-first-century skills. This part of the design and development process was the most difficult and time-consuming for the design team as they had to work across a range of time zones, with different school calendars, as well as incomplete and poor-quality video footage to name but a few operational problems. However, the investment in time and resources were crucial as these video resources are key components in the overall design of the 21CLD MOOC. In addition to illustrating a skill in action, these videos are positioned as the focus of the online discussions in which participant teachers analyze and reflect on the learning observed in each classroom.

While the definition, explanation, and illustration of each of the skills, along with the "in-action" videos, formed a core aspect of each module, the team was critically aware of the need to design opportunities for more collaborative and constructivist engagement with teachers to promote "co-learning" (Laurillard 2016). To this end, focused questions related to the design of learning activities were embedded into each MOOC module. However, to promote meaningful co-learning, there was a recognition of the need to challenge and support teachers as they engage in critical discussions around their understandings and classroom experiences of 21CLD in action. Findings from Phases 1 and 2 clearly indicated it is through such discussions that change in teachers' pedagogical orientations is facilitated and, as such, are a key element of the professional learning model. However, these types of discussions are readily supported through face-to-face interactions. The challenge now is to embed such critical discussions in a MOOC environment. This challenge raises many further questions. What type of design is required to promote critically reflective dialogue through asynchronous online

discussion? To what extent will asynchronous discussion fora need to be moderated and supported by other means such as synchronous “live” sessions?

How to Design Opportunities for Deep Learning Conversations Online?

Currently, any teacher can access the MOOC assets developed for the eight modules of the 21CLD course on the Microsoft Educator Platform. Over **33,657 teachers** from **100+ countries** have participated in the 21CLD online program (February 2016–December 2017), conservatively impacting **3,870,640 students per annum**. The 21CLD program consistently remains in the top ten courses on the Microsoft Educator Platform. However, the content has not yet been designed or hosted on a MOOC platform which would lend toward a more blended model of professional learning. Teachers typically interact with the content on an individual basis, and there is limited scope to engage in critical discussion with other teachers.

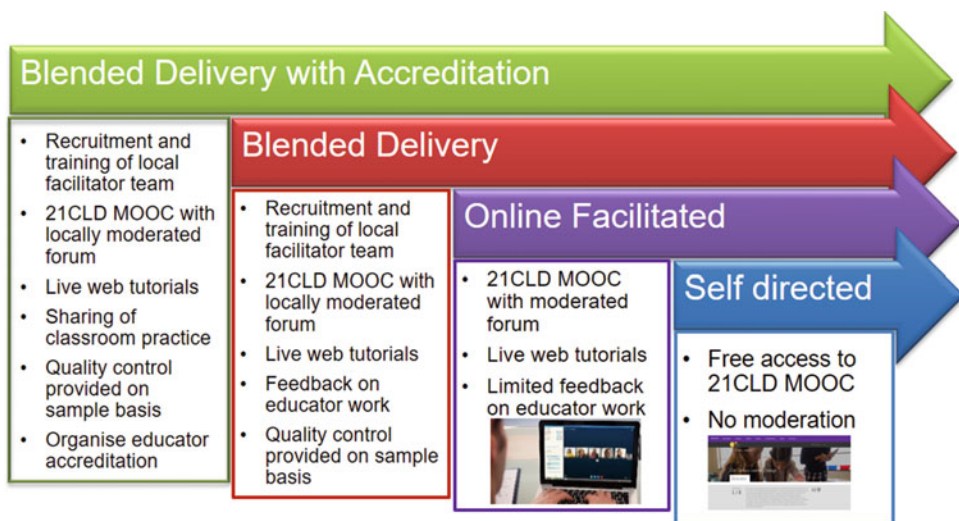
The next phase of development is therefore to take these assets and to relocate them on an intentionally designed MOOC platform where learner experiences can be constructed to recreate the deep professional learning experiences observed in Phase 1 and Phase 2 of the initiative. To this end, Dublin City University (DCU) has recently joined the FutureLearn platform which in terms of its design was strongly influenced by Laurillard’s conversational framework (Laurillard 2002). However, the challenge remains to design the social supports within the MOOC structure to sustain the collaboration, dialogue, and ongoing reflection that are necessary for the changes in pedagogical orientation and classroom practices. In particular, there is a need to establish if the technology exists to do this and, if so, how to successfully embed it in the teaching and learning experience to support the deep engagement witnessed in Phases 1 and 2.

Cognizant of the experiences in Phases 1 and 2, the design team strove to design a MOOC that could reach large numbers while also providing opportunities for teachers to learn through practice, discussion, and production (Laurillard 2016).

In this sense, there is a requirement for teachers both to try out ideas in their classrooms and report back on their experience so that critical reflection and discussion are promoted, thereby providing opportunities for teachers to share ideas and resources. Incorporating these elements would result in scaling the model of teacher professional learning developed to date that is contextualized and meaningfully rooted in classroom practice. There is a recognition that the creation of a community of practice needs to be built around a MOOC, as opposed to individuals just working through the content on their own.

The challenge for the design the next iteration of the 21CLD MOOC is therefore to explore if it is possible to recreate the collaborative nature of peer coaching and develop the communities of practice that can sustain a culture of self-evaluation. Given that professional learning is most effective when it is grounded in collective discussions of classroom practice (Warren Little 2003), our major concern is how to recreate, in an online environment, those deep learning conversations which are centered on teachers’ classroom practices that were central to teacher learning in Phase 1 and Phase 2. Therefore, in the next iteration of the 21CLD MOOC, the intention is to explore if the synchronous online learning tools are up to the job of facilitating deep deliberation, as defined by Brookfield and Preskill (2005). Thus, the only variable that is being changed from Phase 1 to 2 is the medium through which teachers will engage in deep discussion, moving from face-to-face to online, and this affords an opportunity to explore if and how synchronous online learning tools can support such interaction.

Drawing on the review of literature, there is an awareness of the centrality of the role of the online tutor and the development of certain critical “dispositions” (Brookfield and Preskill 2005) so that participants will be able to engage in intense debate and dialogue. All too often it is too easy for facilitators to slip back into transmission and fill the “air” with their own voices (Laurillard 2002; Brookfield and Preskill 2005). The disposition of *deliberation* appears particularly relevant as it is essential to provide teachers with an opportunity to engage in robust debate around their



MOOCs, Teacher Professional Learning and Deep Learning Conversations, Fig. 2 Possible ways that the 21CLD MOOC can be developed

teaching practices. Deliberation has very much been to the fore in Phases 1 and 2 with teachers engaged in robust discussion embedded in their classroom practices. Other dispositions that would appear to be important would include hospitality and mutuality as there is a responsibility on the facilitator to create an atmosphere of trust where learners feel welcome and secure. They need to design “a safe place where learners can be open that allows learners to share” (Brookfield and Preskill 2005, p. 13). Some learners will be very experienced, while others will be shy, so there is a need to create a sharing environment where they can learn from each other (Laurillard 2002).

The literature also suggests that the facilitators’ pedagogical beliefs and their technical knowledge of the online technologies are key to ensuring deep discussions. To this end for the initial pilot phase of the next iteration, the authors will be the facilitators using synchronous online learning tools to facilitate deep discussion with the 21CLD MOOC assets by working with a group of teachers in the southwest of Ireland recruited by the local teacher education center. However, a basic assumption of this so-called 4th wave is that a one-size model of online professional learning will not fit all and that different strokes will be

needed for different folks depending on the educational context (Picciano 2014). Consequently, in addition to this pilot, a range of other possible MOOC deployment strategies are being considered, as illustrated in Fig. 2.

A blended delivery model may be worthy of further development in an effort to scale up the professional learning model, and to this end an accredited postgraduate certificate and diploma has been developed by the DCU Institute of Education.

Conclusion

In conclusion, this entry has discussed a range of conceptual, theoretical, and practical considerations around the potential of MOOCs for scaling up teacher professional learning. In addition, and in keeping with “the cMOOCs focus on community building, social interaction [and] peer review” (Jobe et al. 2014, p. 1581), the authors want participants to be able to work in peer groups, sharing experiences, ideas, and expertise. This type of MOOC design also aligns with our job-embedded approach that recognizes the value of the experience and expertise that teachers can offer each other (Butler and Leahy 2015).

Although, the 21CLD resources are currently available to a worldwide audience on the Microsoft Educator Platform, the authors have still to develop ways that the school-embedded, job-focused model of teacher professional learning can be scaled effectively so that the teacher professional learning experience is contextualized and rooted in classroom practice. The upcoming piloting of the synchronous online discussions as outline above will begin in Ireland in 2018 by working with the national network of teacher education centers. If this next iteration of the 21CLD MOOC is successful and the deep discussions about learning are recreated successfully online, the logical next step would include the identification of cohorts of teachers at local and regional levels that would be capable of supporting others. In this way, the 21CLD MOOC would be recreating in an online environment the collaborative nature of peer coaching and developing communities of practices that would sustain a culture of self-evaluation similar to that which occurred in Phases 1 and 2.

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Multicultural Education

► Intercultural Education in the Digital Age

Multiliteracies

- Digital Technologies and Literacy Contexts for Young Indigenous Children
- Literacy and Technology

Multimodal Learning Analytics

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Synonyms

Learning analytics; Project-based learning; Technology-enhanced learning; Formative assessment; Learning design

Introduction

In recent years, many countries in Europe and the rest of the world have invested heavily in digital skills and connectivity, by digitalizing industries, businesses, and public services. These advancements have been made possible by the dynamic development of technology and new innovative services (Luckin et al. 2017). New data-driven technologies and services imply that individuals need to master new skills to effectively integrate the Internet of Things, big data, automation, and artificial intelligence. In the current times, in addition to the acquisition of new skills, there is increased emphasis on some of the innately human skills, such as complex problem-solving, coordinating with others, critical thinking, negotiation, creativity) (WEF 2016). While the automation of industrial, labor-intensive jobs has been an ongoing trend since the 1960s, the new abilities of artificial intelligence (e.g., IBM's Watson and Google's DeepMind) are slowly resulting in a new digital revolution where professionals, such as doctors, nurses, leaders, teachers, and lawyers, who have high levels of expertise, are seeing their role as experts being challenged and transformed (Government 2017). This high pace of change in future workplaces appears to be an increasingly prevalent aspect of our lives. According to the most recent

estimates of World Bank, over the next decade, more than one billion young people will enter the global labor market, and only 40% will be in jobs that currently exist today (Caught 2016). Given the rates of change in modern working contexts, the fundamental requirements of future workers are to be flexible, self-reflective, and adaptive lifetime learners.

In the field of education, new technologies provide stakeholders with new tools and measures processes that can change the core processes of teaching and learning. Training and education are being challenged and changed by the digital transformation, and education is only gradually equipping students with digital skills such as coding and programming. However, these skills alone are not enough as the society moves towards greater automation. Education is responsible for providing today's students the future workforce with skills that are not prone to automation. The focus of education and training should be on skills that make us different from modern technologies, that are fundamentally human and that require human intelligence. These skills include but are not limited to complex problem-solving, social intelligence, emotional intelligence, coordination with other, creativity, and critical thinking.

One approach to providing these new skills is to provide opportunities to learners to work in unison towards solving complex problems in socially interactive, rich learning environments. Some examples of these pedagogical approaches include practice-based learning, problem-based learning, project-based learning, and inquiry-based learning. Contemporary educational researchers and practitioners have endorsed these teaching approaches by explaining their merits in achieving high-tier learning objectives (c.f. Barron and Darling-Hammond 2010). Today, many countries have formally included these skills and pedagogical approaches into their national curricula. However, many scholars have questioned and criticized these pedagogical approaches because their effectiveness in achieving learning outcomes and ensuring content acquisition has not been backed by evidence (Kirschner et al. 2006).

One of the potential reasons for this apparent lack of evidence is that the higher tier learning outcomes that are expected in such pedagogical approaches are extremely difficult to measure, particularly in dynamic learning environments involving group work and open-ended tasks. Therefore, traditional, standardized measurement methods often fail to show the positive impact of such pedagogical approaches on intended learning outcomes. On the other hand, new advances in learning analytics research, particularly multimodal learning analytics (MMLA), offer novel methods that generate distinctive information about what happens when students are engaged in these activities (Worsley and Blikstein 2014).

The focus of this in this entry is on collaborative project-based learning. New advances in learning analytics research, particularly MMLA, offer improved methods that can generate distinctive information about what happens when students are engaged in such collaborative, project-based learning activities. Such information facilitates new understanding of the complexities of collaboration (Blikstein and Worsley 2016; Grover et al. 2016; Martinez-Maldonado et al. 2017; Ochoa et al. 2014). MMLA combines different types of process data (e.g., log data), collected from diverse sensors, log, and trace files. The focus of the analysis is on the timing (temporality) and order (sequence) of activities that learners use during their collaboration. That said, MMLA is an emerging field and, unlike the more traditional learning analytics approaches, it requires adaptation and the building of systems and the use of sensors to collect data from the physical environment, in addition to digital data.

Current research in MMLA focuses on developing a better understanding of the complexity of learning through high-frequency multimodal data capture, signal processing, and machine learning techniques (Ochoa and Worsley 2016). MMLA offers different insights into learning in project-based learning tasks, where students have to create unique artifacts such as computer programs and robots and engage in small-group collaboration to solve open-ended tasks (Blikstein

2013; Blikstein and Worsley 2016). MMLA builds on multimodal human interaction, educational data mining, and many other fields of learning and cognitive sciences to capture the complexity of learning through data-intensive approaches (Siemens and Baker 2012; Worsley 2012).

Structure and Limitations

This short entry presents a brief background on the emerging field of MMLA and argues for its potential to monitor, support, and evaluate students' skill development during constructivist learning activities. The next section briefly describes current MMLA projects in diverse educational settings, with a focus on learners and teachers. This entry concludes with a discussion on the challenges in transferring MMLA from research to practice.

A Brief Background of MMLA

The chapter starts with the premise that across all levels of education, it is common to encounter situations in which learners work in unison to solve problems in socially interactive learning environments. Many experts in education have advocated the use of interactive pedagogical approaches, arguing that they help learners achieve high-tier learning objectives (Barron and Darling-Hammond 2010). However, not much evidence is available on the effectiveness of these methods (Kirschner et al. 2006), and they have been criticized as being ineffective (Kreijns et al. 2003). However, this lack of evidence may also stem from the fact that the higher tier learning outcomes that these pedagogical approaches help achieve are very difficult to measure. Therefore, traditional, standardized measurement methods often fail to show the positive impact of such pedagogical approaches on intended learning outcomes. MMLA offers improved methods that can generate distinctive information about what happens when students are engaged in such constructivist teaching approaches (Worsley 2014). For

instance, students' collaborative problem-solving competences can be interpreted from their non-verbal physical interactions. Such information can enable a new understanding of the complexities of collaboration (Cukurova et al. 2018).

The field of MMLA is rapidly developing across the domains of formal, informal, school, and workplace learning. Different technologies are being used and integrated, and data from sensors, including biometric and computer vision devices (body, limb, finger, face and emotional, object tracking), are being combined with existing learning management systems that span the physical and digital realms. However, most of the MMLA work conducted is still at best a "system prototype" (technology readiness level 3–4) (Commission 2014) or in other words a "highly functional prototype validated in a lab like environment." To verify and validate the work that has been conducted on MMLA, the MMLA community has to identify ways to make MMLA systems easily implementable outside of research and innovation projects. Such efforts can allow for larger scale interventions and grounding in learning theories in line with the aims of learning analytics community.

Specifically, MMLA involves a combination of different types of process data (e.g., log data). The analysis considers the timing (temporality) and order (sequence) of activities that learners use during their engagement with learning activities. The activities involve, for example, overt and visible activities of self-regulated learning (i.e., planning, goal setting, strategic enactment, and reflecting) (Johnson et al. 2011) and invisible mental reactions, such as emotional states measured from physiological signals (Pijera-Díaz et al. 2016). Thus, multimodal learning analytics combines various data sources that reflect the temporal and sequential characteristics of regulated learning over longer periods of time (Cress and Hesse 2013).

Similar results have been obtained in the field of socially shared regulation and collaborative learning (Molenaar 2014) in more traditional and face-to-face learning environments. However, an

advantage of MMLA is that it allows for capturing of detailed information about learner activities, such as which activities learners use and exactly when they use them. Thus, MMLA allows users to jointly consider both cognitive (visible) and emotional (invisible) processes (Nesbit et al. 2007). It can be useful for designing pedagogical approaches (e.g., prompts or scripts) for individuals or groups. For example, "on the fly" process models resulting from learners cognitive and emotional responses inform users about the type of support learners need (Järvelä et al. 2016). Additionally, MMLA makes visible how different types of pedagogical approaches affect the learning process, and finally, it helps evaluate how and when different pedagogical approaches are effective for learning. This potential of MMLA motivates researchers to investigate complex learning processes that occur in constructivist pedagogical settings, with the purpose of observing, evaluating, and eventually supporting these learning processes with MMLA technologies.

Seminal MMLA Projects

An emerging body of work within MMLA research is focused on small-group work and project-based learning. This work is mainly an offshoot of the initial work by Blikstein and Worsley (Blikstein 2013), which investigated engineering students' design activities (Blikstein 2013; Chen et al. 2014; Ochoa et al. 2013). Blikstein (2011) used multimodal techniques to investigate students learning of computer programming by capturing code snapshots and video and gesture tracking for engineering tasks. Worsley (2014) presented different approaches for data classification that showed how multimodal techniques have a significant impact on the relation between research and learning theories. Both of these initial approaches enabled other researchers to begin exploring MMLA with small groups of students across different subjects. Ochoa and colleagues (Ochoa et al. 2013) presented the Math Data and Oral Presentation Quality Data Corpora that has

enabled the MMLA community to analyze and discuss the different requirements and results within this field. Further, Ochoa and colleagues' (Ochoa et al. 2014) used the existing multimedia processing technologies to produce a set of features for accurate predictions of experts among students solving math problems. Their work illustrated the benefits of MMLA in supporting students' learning in these contexts. Similarly, Chen and colleagues (Chen et al. 2014) expanded the Oral Presentation Quality Data corpus to further examine the feasibility of using multimodal technologies for assessing public speaking skills. Grover and colleagues (Grover et al. 2016) explored the development of computational models of social learning environments; they evaluated the quality of collaborations from the body movements and gestures of programmer pairs working together with acceptable accuracy rates. Moving away from most of the existing MMLA research, which focuses on learners' data, Prieto and colleagues (Prieto et al. 2016) and Martinez-Maldonado and colleagues (Martinez-Maldonado et al. 2016) studied how MMLA can support teaching actions and orchestration in the classroom.

To make sense of complex data streams derived from multiple data sources, MMLA researchers employ various computational techniques. These approaches include logistic regressions (Ochoa et al. 2013), different feature reduction algorithms (Schneider and Blikstein 2014; Worsley and Blikstein 2014), and statistical models to identify features and predict student performance. The suitability of these approaches depends on the main research question and the purpose of data analysis. Accordingly, these approaches provide insights into how to proceed with a multimodal dataset. Regardless of which computational approach is taken, the existing literature shows that MMLA can support education in project-based learning approaches, and it has the potential to provide new means of gathering insights for complex, open-ended learning activities (Blikstein and Worsley 2016), which are otherwise extremely challenging to monitor and support through the traditional standardized evaluation approaches.

Current MMLA

Spikol and colleagues (Spikol et al. 2018) investigated nonverbal physical interactions of small groups of students collaborating on open-ended design tasks. The learning analytics system (LAS) captured different features like how the students move, how close they were, and their social engagement. This study showed that MMLA and state-of-the-art computational techniques could use physical interactions of students (Cukurova et al. 2018) to generate insights into the "black box" of student learning in project-based activities. These types of insights, generated from multimodal data, can then be used to inform teachers about the critical features of project-based learning and can help them support students appropriately in similar pedagogical approaches.

Current MMLA studies include research on how to support teachers with wearable technologies like smart glasses that provide real-time perceptions of student performance for orchestrating personalized classrooms (Holstein et al. 2018). Martinez-Maldonado et al. (2018) have focused on the under-explored area of learning analytics in the context of physical/motor learning tasks and the physicality aspects of "traditional" intellectual tasks that often occur in physical learning spaces. They are developing a theoretical framework that uses distributed cognition theory, the Internet of Things, and multimodal learning analytics. Echeverria and colleagues (2018) have employed data storytelling (DS) to improve data visualizations and how MMLA is communicated to learners and educators. They propose a conceptual model that applies DS principles to questions posed in teacher- and students-facing dashboards, which can provide the right type feedback for education.

Discussion

These different MMLA projects and research approaches highlight the need to develop the technology beyond the different system prototypes. The aim should be to create a flexible framework

the offers some options for collecting MMLA data and connecting this data back to standard systems (LMS and LRS) with slow integration and learning analytics specifications (Kitto et al. 2015). Diverse projects have shown promising results for using MMLA to gain insights about understanding and supporting collaborative work (see Martinez-Maldonado et al. 2016; Blikstein and Worsley 2016; Di Mitri et al. 2017; Grover et al. 2016; Prieto et al. 2016). However, in the absence of systems that are easy to use and test, MMLA faces the same challenges as traditional learning analytics in digital learning environments: it is not only difficult to gain traction and acceptance among practitioners but also challenging to overcome the socio-technical problem of using analytics for education, especially to impart twenty-first century skills (Blikstein and Worsley 2016; Di Mitri et al. 2017; Grover et al. 2016; Prieto et al. 2016). As a step forward in this direction, we believe that MMLA research focus more strongly on presenting its real-world impact for practitioners.

The aim is to push MMLA towards data collection and implementation in real-world educational settings that are ecologically valid. Additionally, there is a need to encourage ways to make MMLA readable to humans and machines (Cukurova et al. 2018), which would enable us to validate the technical aspects of theories of learning (Friend Wise and Williamson Schaffer 2015). Closing the gap between research and practice will enable more extensive access to the systems and tools, providing opportunities in real learning settings. Presenting the use and value of MMLA in real-world education settings would contribute positively towards its extensive use and acceptance by practitioners (Cukurova et al. 2018; Spikol et al. 2018).

MMLA research is still an emerging field, and the type and frequency of data pose challenges that are different from the ones associated with conventional learning information (data logs from LMS system). Various initiatives for open learning analytics platforms (Sclater et al. 2015) and related toolkits to handle new types of data sources (Kitto et al. 2015) need to be explored for MMLA. At the same time, new

processes are required to integrate and aggregate data from diverse sensors that can allow researchers to implement, validate, and extend the current research. Some progress has been made to develop new infrastructures to connect new sources of data to LMS that help guide future work (Deakin Crick et al. 2017; Di Mitri et al. 2017; Martinez-Maldonado et al. 2017).

Since MMLA builds on diverse fields of research from education to computer science more exchanges between them are required to solve the various MMLA challenges. Lastly, small group work, where students create unique solutions to open-end and complex problems, offer challenges that may be technical or related to user experience. New ways to support education are required in order for research to contribute to practice. Global educational policies are changing to include computational thinking and twenty-first century digital skills with a strong focus collaborative work to meet the changing digital needs (OECD 2015). To make learners more adaptive, skilled at creativity, and adept at complex problem-solving, along with other skills, new tools and methods are needed, like the different MMLA projects discussed above. MMLA technologies should be used to change how to design, support, and improve learning and training in order to address changes in the global society.

Cross-References

- ▶ [Artificial Intelligence in Education](#)
- ▶ [Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption](#)
- ▶ [Data Mining for Educational Management](#)
- ▶ [Decision Support Systems and Knowledge Management in Education](#)
- ▶ [Educational Assessment, Educational Data Mining, and Learning Analytics](#)
- ▶ [Game-Based Learning](#)
- ▶ [Games, Simulations, Immersive Environments, and Emerging Technologies](#)
- ▶ [Human, Social, and Ethical Aspects of Information Technology Management Systems](#)

- MOOCs, Teacher Professional Learning and Deep Learning Conversations
- Robotics in Education
- Teacher Education, Thinking About ICT
- Teacher–Student Relationship and Online Social Networks

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N

Narrative

- ▶ Digital Storytelling in Teaching and Research

Narratives

- ▶ Educative Value of Digital Storytelling

National Grid for Learning

- ▶ Computers and Educational Improvement

National information infrastructure

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Netnography

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Online Teaching, Emotions, and Emoticons in Computer-Mediated Communication

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Introduction

The most natural and perhaps richest form of communication is face-to-face communication, but due to the growth of computer systems and Internet usage during the past three decades, new ways of communication have emerged. Computer-mediated communication can be defined as human communication that is maintained or altered through machines. For effective communication, cues other than verbal are important, especially to develop relationships (Walther and Parks 2002). In face-to-face (F2F) communication, emotions are expressed by appearance, facial expression, gesture, and postures, but in CMC social cues are replaced by content, style, and timing of verbal online messages (Walther and Parks 2002). To fill the gap and deal with the lack of nonverbal cues in text-based communication, the interaction has to include some nonverbal cues to express emotion over a period of time.

The term paralinguage was first used by Trager (1958) who defined it in a narrow sense (Pennycook 1985). In 1984 the Education Research Information Center (ERIC) broadened the term to become the “study of those aspects of speech communication that do not pertain to linguistic structure or content, for example, vocal qualifiers, intonation, and body language”

(Houston 1984). This broader definition is consistent with Loveday’s (1982) and used in this entry (Loveday 1982). Emoticons are referred to as “paralinguage of the Internet” (Marvin 1995) and are the graphic representations of facial expressions that many users embed in their electronic text or messages. These symbols are widely known and commonly recognized among computer-mediated communication (CMC).

Carey in his research paper entitled “Paralinguage in CMC” identified five categories of non-verbal cues in CMC: vocal spelling, lexical surrogates, spatial array, manipulation on grammatical markers, and minus feature (Carey 1980). Walther stated that the communication channel must adapt the language to fill the gaps of F2F cues filtered out with some other verbal text-based cues in CMC such as emoticons (“☺”), vocal spelling (“Weeelll, Hummmm”), and grammatical marks (“!!!!, ???”). The nonverbal cues in F2F communication can be replaced by these other paralinguage cues in computer-mediated communication; however, it is important to know how these cues are used. This entry is concerned with presenting and exploring the use of emotion in online and computer-mediated communication.

Computer-Mediated Communication (CMC)

Initially CMC was criticized as not a proper medium for communication for long-term relationship building and that it was more usable for task-oriented communication rather than relationship building (Walther and Parks 2002). However, the theories and literature in regard to CMC have shown that emotional communication and relationship building are possible through CMC. Cues filtered out and cues filtered in theory have suggested that absence of nonverbal cues in F2F is completed by paralinguage cues, chronemics cues (chronemics is the study of time in communication), and some other verbal cues, so in this section, we will review literature regarding how emotion is represented in CMC.

In his paper “Expression of Emotion in Text-Based Communication,” Jeffrey Hancock

conducted a study of how people express and detect emotion during text-based communication (Hancock et al. 2007). The empirical research suggests that most of the cues, which express emotion, are filtered out from CMC (Walther and Parks 2002). Nonetheless, according to Hancock, the display of emotions through text-based communication differs according to their positive and negative emotional state (Hancock et al. 2007). Positive and negative emotions can be uncovered by identifying agreements and disagreements. If too many disagreements occur, it leads to negative emotional chat, and enough agreement leads to positive emotional talk in text-based communications.

Another way to calculate emotion in text-based communication is in identifying different punctuation-like exclamation “!” and question marks “?”. Such punctuation used in communicating makes text-based communication more similar to voice tones and displays emotion through text. The speed of communication is yet another way of calculating emotion, in that if two people are exchanging information through chat too quickly, it is a signal of positive emotion through text-based communication.

Paralanguage Use in CMC

To express emotion further in computer-mediated communication, some paralanguage cues were introduced, and as stated earlier, Carey identified five categories of nonverbal cues in CMC (Carey 1980): vocal spelling, lexical surrogates, spatial array, manipulation on grammatical markers, and the minus feature. Briefly, these are:

1. Vocal spelling: Vocal spelling such as “Weeeelll” is used to express emotions such as frustration, tiredness, and a bored expression. In verbal expression “Weeeelll” shows tiredness of the communicator, but expression meaning changes with context.
2. Lexical surrogates: Lexical surrogates such as “mhmmm” use nonstandard spelling that imitates vocal information or tone.

3. Spatial array: Spatial array is a set of characters; when we read them all together they make some special symbol or meaning, for example, smiley “☺”: it is made of “:”, “-”, and “)”, these all three together display a happy face all together.
4. Manipulated grammatical marks: Manipulated grammatical marks such as (...) indicate pause, (!!!) express puzzled expression, and capitalization of words inform shouts or importance of sentences.
5. Minus features: Minus features refer to an absence of certain language standards that refers to the relaxed mood of the communicator, like a lack of use of capitalization for the starting of a sentence, or writing intentionally a wrong name or words (to show that both sender and receiver are known to each other), or removing of some words from or making them acronyms like “Lots of Laugh” to “Lol” and for your information “FYI”.

These all show a relationship from formal toward personal in CMC; the cues show that there are some which replace vocal nonverbal cues of F2F communication in text-based CMC from theory cues filtered out.

The uses of CMC cues such as nonstandard or multiple punctuation (“...”, “!!!”), lexical surrogate (“hummm, Ohhh, Okay”), stretching of syllables (“Friiiiend”), and capitalization are context sensitive. To know the actual meaning, we need to consider verbal and nonverbal cues equally. On the basis of context, lexical surrogate (“hummm”) means mitigated disagreement, multiple punctuation (“...”) is used to make some pause or discussion, and multiple punctuation (“!!!”) is used to aggravate disagreement, to mock disagreements, or to show exercise of power depending on context and uses. Stretching of syllables and capitalization emulates spoken nonverbal speech. Capitalization can be used to display loudness or pitch. Frequency of use and multiple punctuation is also dependent on production effort for symbols through the keyboard and is mostly observed in equal amounts (Vandergriff 2013).

Online Teaching, Emotions, and Emoticons in Computer-Mediated Communication, Table 1 Types of emoticons and paralanguage cues and their uses according

to literature research (Carey 1980; Chen and Liu 2006; Rezabek and Cochenour 1998; Vandergriff 2013; Walther and D’Addario 2001)

Name of cues	Graphical representation of cue	Intended meaning	Emotional side (positive/negative/mixed)
Smiley	☺ :-)	Happy, solidarity, support	Positive
Sad	☹ :-)	Sadness, negative, feeling, despair, confusion	Negative
Wink	;-)	Humor, teasing, sarcasm	Mixed
Teasing	:p	Teasing, sarcasm	Mixed
Intensify laugh	:-D	Huge happiness, sometimes sarcasm	Positive
Multiple full stops	. . .	To give praise in conversation or to give time to think, concern	Mixed
Multiple elimination	!!!	To show excitability or high affects, sometimes also display confusion	Mixed
Lexical surrogate	Hmmm	Convey skepticism or disagreements sometime	Negative
Capitalization of words	PLEASE DISCUSS	Convey loudness or stress, emphases	Mixed
Extending spelling	Friiieeennddss	Sometimes use as F2F nonverbal cues for giving stress on point by focusing on it	Mixed

Emoticons and their Use in CMC

Emoticons are graphic representations of facial expressions that many users embed in their electronic text or messages and are referred as “paralanguage of the Internet” (Marvin 1995). In regard to the display of facial emotions, similar to that in F2F communication, computer-mediated communication replaces those cues with emoticons. The emoticon is constructed of two words “emotion” and “icon,” and the main purpose of emoticons is to convey nonlinguistic information that face-to-face communication depicts with facial expressions, as depicted in Table 1. Emoticons are highly used cues in CMC for displaying emotion through ASCII keywords, which resemble the face in text-based communication. A definition from pioneer researchers in the field of CMC for emoticons is as follows: “An ASCII graphics used to indicate emotional state” (Walther and D’Addario 2001). Emoticons are also known as visual and graphical cues formed with ordinary keyboard typographical symbols that when read with text written before and after that symbol represent emotions of senders (Rezabek and Cochenour 1998).

Smiley faces ☺ were introduced by a computer scientist at Carnegie Mellon University, Scott Fahlman. When changing the position of the “)” character to “(”, it becomes a “frowny” face “☹”. Smiley has evolved from ASCII characters to graphics, and nowadays many action cartoons are being used by CMC channels (Dresner and Herring 2010). In the research paper “Function of the nonverbal cues in CMC,” the researcher explained that use of the smiley has a cultural touch also in CMC (Dresner and Herring 2010) and explained that use of CMC emoticons varies according to culture; for example, in Japanese conversation they use “Kaomoji” (^-^) which resembles a happy Japanese face.

Walther and D’Addario studied potential effects of emoticons for expression of emotion of two types – affective positive and affective negative – which showed that it is true that the effect of emoticons is strong in overall interpretation of messages (Walther and D’Addario 2001). According to the study, there are two types of uses of emoticons, where one is used to strengthen a message and the other use makes the message ambiguous, as it contains mixed

feelings with nongeneric use of emoticons. In their research paper “The Impacts of emoticons in message interpretation,” Walther said that the intensity of a message mostly comes in only verbal text as is written. He said that nonverbal cues such as smiley and paralanguage cues sometimes tone up the meaning or interpretation of the message. Walther and D’Addario in 2001 worked on the analysis of positive effects of emoticons in positive texts sent by a sender. They also related information regarding mixed uses of emoticons in CMC. For example, they studied when a normal message or negative message is sent by a sender with positive emoticon or when a positive or normal message is sent with negative emoticons. This conveys mixed feelings in the sentence and thus to the receiver. Such uses of emoticons are ambiguous, and according to Walther, it is hard to understand the true feeling of a sender in such messages (Walther and D’Addario 2001).

Winks as emoticons are very ambiguous to interpret, just as the meaning of some emoticons can be ambiguous. It is constructed with a half smiley “:-)” and half part of winks “p”. Winks suggest other dimensions of feeling such as sarcasm or humor. These kinds of emoticons give a message a sarcastic tone (Rezabek and Cochenour 1998; Walther and D’Addario 2001).

An Online CMC Project and Emoticons

The behavior of displaying emotion through emoticons, punctuations, lexical surrogate, capitalization, and other cues varies in the context of CMC settings and depends very much on whether it is monitored, non-monitored, one-to-one, or group communication. It also confirms individuals’ perceptions of social presence in the visible and non-visible chat conditions. As reviewed in the literature, the degree of social presence is more affected by visibility than monitoring ability since the delivery of nonverbal cues through visual channels plays a critical role in perceiving social presence (Daejoong et al. 2013).

A study based on a qualitative content analysis of students’ text-based synchronous online communication from an inter-institutional online course on computer-mediated communication and remote collaboration was conducted, and data collected over a 5-year period support these findings (Connolly et al. 2017). The project was part of software engineering-related courses at 3 institutions in Europe, with a diverse ethnic grouping and age band; on average, approximately 60 students attended the course with one-third of the students female and two-thirds male. The undergraduate and postgraduate students had several online meetings during each week of the project duration and all team communication recorded. The students were aware and understood that all communication would be analyzed for research purposes and to determine their contribution to the remote collaboration, i.e., the chat logs were also relevant for the grades they received as part of their course of study.

The research question aimed to discover how different emoticons and other paralanguage cues were used in CMC in terms of frequency of use within the student population. The chat logs were analyzed and had the following characteristics:

- Available data was purely text-based.
- Data generated by mixed working groups (mixed in terms of nationality and gender).
- Chat logs showed a variety of characteristics in terms of communication; for example, it had instances of introductory communication, team building, decision-making, emotion and disagreement in communication.
- Chat logs had a wide variety of paralanguage used by communicators.

The research findings, regarding the use of emoticons and paralanguage cues, demonstrated the reliance on emotion in communication by the students, through both positive and negative reinforcement of the message (Connolly et al. 2017). The findings showed how emoticons (“:-)”), nonstandard/multiple punctuation (“...”, “!!!”),

lexical surrogates (“hummm, Ohhh, Okkay”), stretching of syllables (“Friiiiend”), and capitalization are used in a computer-mediated communication remote collaboration project and the frequency of use of emoticons and other cues. The students, at times, used emoticons and paralinguistic cues in support of the verbal sentence, and there was also evidence of the use of such features, contrary to the meaning of the sentence. Lastly, the use of emoticons and paralinguistic cues could be ambiguous and affect the message, signified by the overuse and overreliance on emoticons or paralinguistic cues in conveying their message.

Such results establish at least three different kinds of use visible in CMC for emoticons and paralinguistic cues. Most popular and common use was to strengthen a message by using emoticons, which supported verbal messages, and in such cases, the interpretation of emoticons was straightforward. The second use was in mixed messages, when use of emoticons and paralinguistic cues did not match the verbal messages’ meanings and where interpretation of emoticons used was ambiguous. The third use, visible in CMC, occurred when there was an overuse of emoticons and paralinguistic cues. There is also evidence that there were emoticons and paralinguistic cues used in sentences, where it did not add any emotion to the sentence, and these were visible often.

Conclusions

Emoticons play a significant role in clarifying message intention, compensating for the absence of nonverbal cues, and there is clearly a prevalence and frequency of use among university-attending students. Notwithstanding these observations communication is rapidly evolving through the use of electronic means, and the findings show the reliance on paralinguistic and emoticons in our electronic communication to compensate for one of the most important cues in human communication, facial expression. Paralinguistic cues and emoticons contribute to a social presence in an electronic

world and enrich the text-based communication channels.

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Online Training

► [Formats of Virtual Learning](#)

Open Educational Resources and Distance Learning, Challenges and the Way Forward in Higher Education

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Synonyms

Action plan; Confrontations; Correspondent learning; Free learning materials; Media assets; Open license texts; Remote learning; Tertiary education

Introduction

The whole world is now striving toward achieving universal access to high-quality education which is the key to the achievement of peace and sustainable social and economic development. In a bid to help learners in utilizing high-quality educational content and materials, open educational resources (OER) present free accessibility to essential content as well as opportunities for reusability and sharing (Willems and Bossu 2012). Open educational resources are free learning resources accessible and available on the Internet. OER can be defined as “materials used to support education that may be freely accessed, reused, modified and shared by anyone (Downes, 2011). In a related vein, OER are teaching, learning and research resources that resides in the public domain or have been released under an intellectual property license that permits their free use and re-purposing by others. OER include full course, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge” (The William and Flora Hewlett Foundation n.d.).

As pointed out by Commonwealth of Learning (2013), OER can be openly licensed or can be put in the public domain, to use or reuse freely. They

can exist in many formats such as text print or electronic, audio, video, multimedia, or hypermedia, or in combinations of all. OER can also be based on a single learning including a lesson, a series of lessons (a module), whole course, or even an entire program of study. OER can support a specific methodology or approach, be it constructivist and or behaviorist or combination of both. There may be differences in format, structure, or approach, but they still share a common characteristic that is openness.

OER are actually open implying that with open license, the person who create retain ownership of their work and can specify how open they want their resources to be, i.e., from fully open to closed for a particular purpose. Compared to commercial resources, OER can be used and reused as needed and desired by learners and teachers. Similarly, they can (Commonwealth of Learning 2013) be edited to reflect the styles and approaches of the users, can be managed by the insertion of new materials as it becomes known or available, and can be customized, repurposed, or adapted to reflect the others of your organization.

As open educational resources are useful in the regular learning, so also it is to the distance learning. Online learning started as a type of distance education technology in the 1980s and 1990s. Other distance education technologies were paper-based correspondence courses and later video- or satellite-based along with some other technologies. What differentiates online learning is that transmission occurs through the Internet-connected computers, while in the distance education, students and faculty do not need to be in the same place at the same time.

The role of distance education is changing drastically both at micro and macro context. Education has no longer remained the prerogative of institutions, or even knowledge has no longer remained under the sole control of teachers only. Through OER, an effective platform has been created not only in strengthening the open and distance education in the developing nations where there has been real shortage of creating knowledge pool for developing useful courseware but also empowering them to build their capacity to participate effectively in producing the open

courseware. However, much have been done in the area of OER. Researchers have looked at the issue holistically in terms of conceptualization, benefits, opportunities, and challenges within the context of regular learning mode; however, discussion on OER as it relates to distance learning particularly in the developing countries has not been so much researched and discussed. It is on this note that this entry looks at OER in terms of concept analysis, evolutionary background, impacts and relevance to the distance learning, challenges, and the way forward.

Concept of Open Education Resources

Open educational resources can be described as “technology-enabled, open provision of educational resources for consultation, use and adaptation by a community of users for non-commercial purposes.” They are usually made freely available over the Web or the Internet. They comprise of learning objects such as lecture material, references and readings, simulations, experiments and demonstrations, as well as syllabi, curricula, and teachers’ guides (UNESCO 2002).

The concept includes free (that is no cost is charged) and open (for update and modification) resources such as digital content, open-source software courses; course-related materials such as syllabi, lecturers, lesson plans, and assignments; textbooks; or collections of digital media including libraries of images and videos (Geith and Vignare 2017). The truth about OER is founded on the academic traditions of freely and openly sharing and extending knowledge (OECD 2007). In this manner, OER extend the concept of the public commons, as well as the ideas of open-source software into education (Udas 2007).

Open educational resources are teaching, learning, or research materials that are available to the public or released with an intellectual property license that gives room for free use, adaptation, and distribution (UNESCO 2009). They are available freely for everyone to use or reuse, whether a person is an instructor, student, or self-learner. Prominent among them are full programs, program modules, curriculum materials

from teaching sessions in different formats, assessment resources, assignments from quizzes to exam papers to e-assessment, lab classroom activities, teaching materials, games and simulations, and many more resources, contained in digital media collections around the world (JISC 2013).

OER can be regarded as a subset of broader term which is open education. As put forward by the William and Flora Hewlett Foundation (n.d.), open education is the simple and powerful idea that the world’s knowledge is a public good and that technology in general and the World Wide Web in particular provide a distinctive opportunity for all to share, use, and reuse the knowledge. In furtherance to this, open educational resources are digitized materials provided freely and openly for educators, students, and self-learners to use and reuse for teaching, learning, and research. For further clarification, open educational resources encapsulate:

- Implementation resources: Intellectual property licenses to promote open publishing of materials, design principles of best practice, and localize content
- Learning content: Full courses, courseware, content modules, learning objects, collections, and journals
- Tools: Software to support the development, use, reuse, and delivery of learning content, including searching and organization of content, content and learning management systems, content development tools, and online learning communities

Arising from the series of definitions, it can be deduced that “OER” are both large and indefinite. A great diversity of objects and online materials can be categorized as educational resources, from courses and course components, to museum collections, to open-access journals and reference works. Over the years, the term has come to cover not only content but also learning and content management software and content development tools and standards and licensing tools for publishing digital resources, which allow users to adapt resources in accordance with their cultural,

curricular, and pedagogical requirements. The following section features the different types and elements of OER beginning with an illustrative figure.

Why OER in Distance Learning?

OER, open educational resources, are supported by educators who believe that sharing is important for learning. They wanted to use affordable (free) learning resources; have the legal rights to use these (free) learning resources; have updated content; translate resources into other languages; broaden access to learning; and ensure publicly funded educational resources are available to the public (Commonwealth of Learning 2013).

As agreed generally, the main purpose of the OER is to create an opportunity for open-access to high-quality digitized educational materials for building capacity at all levels. Due to eruption and ignition of knowledge and advancement of information and communication technology (ICT), there has been huge and colossal requirement for one to update herself/himself, and as a result more number of participating institutions/agencies are joining this digitized club with the basic philosophy of openness. It could therefore be observed that the basic rationale for the need of OER basically is due to the following (Jena 2010):

Capacity building: OER endeavor is made possible not only as an opportunity in building the capacity of the individual but also of the institutions through effective networking. For instance, the teachers have to search for materials having capacity to be useful resources based on the most updated knowledge, which further enables them to adapt and reuse and thereby remarkably assists them to build their own capacity, and also they can further contribute for modifying the resource materials by providing essential feedback out of their own experiences.

Access and distribution of learning resources: OER assist in ushering collegiality and online collaboration among the educators who not only share development of learning resources but also help increase the quality of learning resources that are available beyond the four walls of the

classrooms. Since the learning materials are available at the public domain for use, which otherwise would have remained inaccessible.

Best practices: OER are majorly stored in databases or repositories. Since process of documenting the resources is undertaken scientifically, hence there is ample scope to store the best practices in the form of source form, which are usually unseen. This helps both educators and the organization to show the practices in their local situation with suitable adaption.

Collaborative efforts: The idea behind OER basically enhances in cooperating efforts in creating learning resources, more specifically in the context of developing countries. As the whole effort of collaboration is online, the materials can be infinitely customized, and the availability of appropriate free content license is also ensured. Thus, this enables the professionals to lead developments and contribute immensely to the knowledge community as active partner. These collaborative efforts facilitate in material development process and help in empowering educators to demonstrate their potentialities.

Research: OER have strong component of research. Any resource material gets developed under the free content principles and in a collaborative manner requires having strong basis of research. Since its primary goal is to create and host free content, multimedia learning materials, resources, and curricula for all age groups irrespective of languages, a scientific method of approaching the material development process becomes a component of basic research. In the same vein, the efficient use of these materials and feedback generated helps to further enhance the quality of resource materials.

Evolutionary Background of Open Educational Resources

The development of OER in higher education in the twenty-first century is part of the much larger social movement toward opening up what was formerly closed to all except a limited number of people who paid for access to use information and services. In the late 1990s and early 2000s, a

number of OER initiatives were launched at universities with support from public agencies and private foundations; chief among these is the William and Flora Hewlett Foundation. These attempts generated openly available course syllabi, textbooks, math education materials, and platforms for user-generated content. Recognizing the challenge of locating and vetting OER content, the National Science Foundation also funded development of curated pathways to open instructional content on the Web. In these years, countless domain-specific online resources have been created and deposited either with major platforms or on university and college websites and repositories. OER admirers' communities have collaborated with major gatherings such as the OpenED Annual Conference. Later, OER proponents introduced services to buttress successful OER integration by universities and colleges.

As D'Antoni (2009: 3) points out, the OER movements are a young movement with just a decade of development. It had its beginning in 1999 through grassroots project such as Richard Baranuik's initiative at Rice University that eventually became the Connexions project (Baranuik 2008) and through large-scale institutional initiatives, such as MIT's OpenCourseWare (OCW) project (Carson 2009) which inspired others such as Johns Hopkins Bloomberg School of Public Health. Other institutions such as the Open University (OU) in the UK and Open University of the Netherlands (OUNL) also joined the OER through somewhat unexpectedly as, unlike a traditional campus-based institution such as MIT, their core business is distance education.

International efforts have also played a major role. In the UK, substantial investments from the Higher Education Funding Council and the Joint Information Systems Committee funded a program to support both open content creation and technical infrastructure (Allen and Seaman 2014). In the year 2005, the OCW Consortium was launched to provide an international forum and community, and in 2007, an international convening conference aiming at promoting OER resulted in the Cape Town Open Education Declaration which was signed and embraced by many enthusiasts (Bakia et al. 2015).

Relevance and Impacts of OER on Distance Learning/Education

Many effective and efficient OER platforms have been created to strengthen the open and distance education in the developing nations, where there has been shortage of knowledge creation for developing useful courseware, and also empower them to build their capacity to participate effectively in producing the open courseware. It has potentials to facilitate the open and distance education system in the following ways (Jena 2010):

Professional growth: In most of the developing nations, the ODL institutions are basically targeted for meeting the educational needs of the disadvantaged groups. OER facilitate in enhancing personal knowledge of both distance teachers and learners through effective planning and active support of ICT. It also helps the distance teachers to undertake systemic researches in a more scientific and objective manner and quickly share the same across the professionals.

Repository of learning content: Free learning contents get developed in the form of full courses, courseware/course materials, and content modules, learning objects, collection, and journals with the joint support of online communities having common interest. The physical distance between the experts has been almost reduced in the process of sharing the ideas and process of developing the courseware. The collective responsibility calls for standardizing the courseware in a more scientific way suitable in the various contexts.

E-learning initiatives: A strong network is being created for successful planning, designing, development, and implementation of materials necessarily to be used for effective e-learning, which most of the distance education institutions have been contemplating around the world. This calls for building the capacity of professionals via such open materials which could be shared, used, and reused in the context. Similarly all components of e-learning could also be facilitated, be it learning through online, assessment procedures, admission, other administrative issues, etc., through the support of open courseware. The

open and distance learning (ODL) institutions have strong potentiality of sharing the software to support the creation, delivery, use, and improvement of open learning content.

Licensing under Creative Commons: There has been always a feeling that the open and distance learning (ODL) system undergoes tremendous pressure on the intellectual property licenses to promote open publishing of materials, production of best practices, and localization of content. Since the production of OER goes beyond the scope of the institutions that primarily take initiatives in creating the materials, multiple partners join in the process with the objective to further strengthen the content. Further the materials are created and licensed under a “Creative Commons” used freely online, and hence it no longer remains the property of one individual and organization. “Creative Commons and other open licenses allow materials the potential to be readily reused in an OpenCourseWare or other educational product” (Caswell et al. 2008: 12). Since materials are freely available and their use and adaptation are encouraged under the Creative Commons license, the ODL system can be strengthened particularly in the context of developing nations.

Forum for professionals: With the support of online communities, the ODL system gets facilitated to establish the forums of professional discussion not only within the boundary of one nation but also beyond. The initiative of COL through its project WikiEducator is worth mentioning to bridge the digital divide in the context of empowering underdeveloped and developing nations. The whole initiative also extends maximum benefits to such small Commonwealth nations through its project Virtual Universities for Small States of the Commonwealth (VUSSC), which otherwise would have never been benefited due to their dispersed sociocultural reasons. As the ODL institutions are brought to the network, the professionals of these institutions collaborate virtually on national and international initiatives, which is more cost-effective. The cost on course development process and its delivery remains almost negligible as the materials are accessed anywhere at any point of time.

Consortium for course development: As has been observed, a growing momentum is taking place among the distance learning institutions to participate in the course development process by forming consortium for OpenCourseWare development. Many of the distance learning institutions have committed to launch an opencourseware Website with the primary objective to share their courses. The open courseware (OCW) consortium is established online to assist the OCW movement worldwide. The member institutions are linked with the consortium site real time. In fact the participating institutions can upload their syllabi of the course, lecture notes, assignments, and examination requirements through the consortium site. Through this OER initiative, each ODL institution will have potentiality to create its “learning object repository” for the effective use of its learner and thereby will meet its social obligations.

There are a number of perceived impacts and limitations in the use of OER in distance education (Lane 2010; Hatzipanagos 2012, 2013). They are seen to be displaced from proprietary “silos,” i.e., the institutional virtual learning environments, hence breaking the authorization barriers that these impose and they also copyright “free,” as contributions to collective knowledge. However, they most often come against recent improvements in creation of technology-enhanced learning content, as they can be didactic in nature, the reason being that interaction is frequently nonexistent or poorly scripted in OER learning design. They are also often compact shells to fit within context and meaning. Context and wraparound activities are missing as interactive aspects and their learning design are separated from content and are both implicit rather than explicit (ibid.).

According to the Commonwealth of Learning (2015), the benefits of open education include the following: open to anyone; ideally affordable and free; students can try the course before signing up; flexible study times not bound by weekly timetables or semester calendars; students work at their own pace; available from anywhere and not restricted by access to school or college; access

to huge amount of study materials; and intellectual capital is available for reuse.

Commonwealth of Learning (2013) explained further that OER are a significant component of making open education possible. As has been seen from the preceding definitions, OER are free; are digital (also non-digital), accessible through the Internet and not bound geographically; adaptable, allowing others to repurpose them for new uses; support learning at one's own pace; and allow access to huge amounts of data and information through OER repositories.

OER are believed to provide economies of scale as the same resource that can be reused in a variety of different teaching contexts and provide instances of good practice to help academics improve their teaching (Conole and Brown 2018). Baranuik (2008) lists the principles underpinning the open education movement including knowledge should be free and open to use and reuse, collaboration should be easier, individuals should receive kudos and credit for contributing to education and research, and that concepts and ideas should be linked in unusual and surprising ways and not in the simple linear forms presented in today's textbooks.

There was an ingenious assumption that simply making OER available in repositories would mean that they would be used by teachers and learners; however, evaluation of early OER initiatives such as the Open University UK's OpenLearn repository showed that this was not the case as the take-up by teachers and learners was low (Lane and McAndrew 2010). There is now an understanding of the barriers to using OER (De Hart et al. 2015).

Commonwealth of Learning (2015) also added that there are many benefits associated with the use of OER in addition to sharing which is an important component of any educational experience. With OER, the author retains ownership of his or her copyright without having to assign it to a publisher, thereby protecting and preserving the author's rights. Moreover, open licenses require that attribution be given to the author when an OER is reused, revised, remixed, or redistributed. Plagiarism problem is less when a work can be freely copied. There is no incentive to lie about the

source or to deny attribution. OER are also an excellent way of marketing an institution and spreading its name internationally.

Challenges of OER in Distance Learning and the Way Forward

Within the realm of open and distance learning, the potentiality of OER is restricted to sharing the resources purely for the academic pursuits. If OER are specifically designed to support a courseware, through the Creative Commons and by using electronic resources, it is also essential to find out the means on how to make it largely available in the local context where technology is not supportive and effective particularly in the developing nations.

The developing nations need to be supported extensively when it comes to the issue of making available the free software tool that can enable any individual to download the materials, adapt them to meet the localized needs, and contribute to the field of knowledge through the consortium of creative commons under copyright and licensing. There is also the need to develop extraordinary feedback apparatus or system to study the efficacy and usability of the materials which is supposed to assist dispersed targets with diversified needs through online learning environment.

The OER movement is linked vertically and horizontally within terms of creating awareness and developing effective network of professionals. This is essentially needed by way of ensuring quality materials are kept for use and to address the issue of sustainability which is inbuilt to a new approach for flexible learning and sharing of knowledge in the open distance learning (ODL) context.

It should also be noted that most of the OER initiatives in our institutions are undertaken on a project basis and supported by external funding bodies. For the movement to be very strong, prosper, thrive, and sustained, the whole initiative needs to be institutionalized particularly in the context of ODL system.

Aside from the aforementioned challenges, others which can be discussed are technical

constraints such as lack of interoperability and unavailability of technical specifications as indicated by (Tuomi 2005). This is assumed and can limit openness. Similarly, the learning resources can be used but are usually passworded in learning management systems and not available to external users.

There is also social constraints issue. This is sometimes institutional or economic. For instance, copyright can limit access to resources. Ethical standard associated with research and study can as well limit access. Mentioned can be made of privacy reasons. Social constraints are complex systems with conflicting tensions, where money can buy more access and political power can be used to change institutional constraints.

Hatzipanagos and Jon Gregson (2015) investigated the constraints and barriers in using OER. A key constraint according to the respondents of the survey was a limited understanding of their value. They also alluded to a cultural resistance whose facets were a “new thing,” “not developed here,” “can we trust it?,” etc. However, the main, often repeated perceived barrier in discussions was a lack of staff development to familiarize academics with the nature and opportunities of OER and time to search and explore repositories of OER for suitable learning and teaching resources. This is similar to the investigations by UKOER/SCORE 2014, where lack of digital literacies does feature highly as a barrier to OER, although follow-up interviews that were carried out suggested that finding/evaluating quality OER is a time issue not a skill issue, and likewise many staff avoid releasing OER due to the time involved in making them sufficiently polished and fully compliant to legal issue.

Another prominent challenge associated with the use of OER is the issue of finance. Finance undermines the potential to build the capacity of developing world education systems because it focuses on the spending of money to produce OER in the developed world. As long as financial resources of this kind are expended predominantly in the developed world, there is likely to be little progress in developing the capacity of

developing world education systems to meet the needs of their learners.

Another important challenge that undermines the transformative potential of OER has been an increasingly heated debate around commercialization of “free content.”

This debate most often finds practical expression in arguments about Creative Commons licensing framework and whether or not it is a welcome idea to impose what is described as a “noncommercial” restriction within the license. The reason that this argument has emerged is that, to many people, the concept of creating a noncommercial restriction seems intuitive in order to prevent unfair exploitation of “free” content. However, as many have argued passionately, it has turned out that such a restriction can have several unintended results in the long term, preventing the “mixing” of content with different license conditions and creating unforeseen complexities. These critics go on to observe that the share-alike licensing condition in the Creative Commons licensing framework serves effectively the same purpose as a noncommercial restriction by requiring derivative works to be released under similar licensing limitation by requiring derivative work to be released under similar licensing condition as the real content on which the derivation was anchored. They are also of the opinion that closing down the possibilities for commercial exploitation of derived works may result in long-term problems in sustainability of the emerging educational commons. It is evident that many of these proponents are pushed by a well-desired motive to see content made free, mirroring similar debates that have surrounded open-source software. There is a necessary cause to some extent, but frequently results to logical leaps of faith that are not yet sustained by meaningful evidence that can be educational challenging.

The most noticeable is the belief that making content free to copy, adapt, and exploit commercially in and of itself will lead to better education delivery, particularly in the developing nation. Relating to this is the assertion that free content is the same as educational content. It is evidently possible that free content will make a contribution to improving education; however, this assumption

needs to be proven through demonstration and good practice, not claimed as a fact without evidence. Those who subscribe to educational potentials and quality of OER as a fact without providing supporting evidence erode or subvert the weight of their own argument among skeptics of the OER movement. Numerous concepts such as open learning, distance education, and e-learning have less popularity in terms of potentials because they have been associated with wild claims about the educational impact they would have that have not been borne out in practice. The supporters of the concept of OERs associated removal of unnecessary licensing restrictions that might govern them could be usefully seen to prove this potential through demonstration and good practice not rhetoric. Essentially, it is censorious and analytical to recognize that making content free is only one aspect of which may require to ensure that the quality of education is systematically configured and improved. This apparent fact is frequently lost in the arguments that have emerged, thereby drifting attention away from the critical broader argument about education configuration that can be catalyzed through discussions on OER. Associated with this concern is the point that, even, several proponents of the argument against non-commercial restrictions that the emerging opinionatedness or assertiveness being exhibited by opponents of non-commercial restrictions serves only to oppress those who are taking the first temporal actions towards freeing up restrictive license governing their educational content. The school of thought holds that a spectrum of license is necessary to give people and organizations the choice in deciding the best way to start contributing to the growing pool of available OER. This seems to make sense practically. If a person or institution is designing a course and can distribute to learners a specific journal article free of cost, but is not allowed to modify its text, this seems preferable than not being able to use it at all. Similarly, there may be forceful or irresistible cases for making sure that in some instances, content that is made available for use should not be open for modification, for instance, journal



Open Educational Resources and Distance Learning, Challenges and the Way Forward in Higher Education, Fig. 1 Types of open educational resources. (Source: ALA Annual Conference 2016)

articles or treaties which report specific research findings or encapsulates a special perspective.

The Way Forward

It should be noteworthy that to be successful and sustainable, development of OER in distance learning cannot be unrecognized or ignored within a university. It must be unified into institutional processes in order for both to grip its potential and provide for its sustainability. Likewise, institutional policies, particularly around intellectual property rights, remuneration, and promotion, need to be modified and habituated to support intellectual property rights, remuneration, and promotion and need to be adapted to support and sustain development and use of OER for distance learning, to methodically and invariably improve and update curricula and teaching materials, lessen operating costs, develop institutional capacity, and manage growing distance learning students group successfully.

The promise or capability of OER in distance learning involves bringing lucidity and transparency to educational procedures, enabling cooperation between faculty members and students at

different institutions, and initiating a new economic stereotype or idea for securing, preparing, issuing, or publishing learning materials. Fundamentally, crucial and indispensable to the success of OER in distance learning will be to demonstrate that in the short to long term, it will assist highly occupied faculty members to control their work more successfully, instead of combining additional work requirements to their job responsibilities. However, effective OER ideas or movements will be the one that function immediately and add educational value with the available information communication infrastructure challenges of any participating institutions inclusive of those from developing nations. Demonstrating the quality of a concept that will only have effects when the infrastructural limitations are eliminated is of little merit to higher education institutions in their little to middling term.

Cross-References

- [Distance Learning](#)
- [E-Portfolio in Higher Education](#)
- [Flexible and Distance Learning](#)
- [Tablet Use in Higher Education](#)
- [Technology Enhanced Learning](#)
- [Technology-Enhanced Learning in Programming Courses, Role of](#)

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Open License Texts

► [Open Educational Resources and Distance Learning, Challenges and the Way Forward in Higher Education](#)

Open Source

► [Creative Commons](#)

Orchestration

► [Rationales for Information Technology in Schools, Historical Perspective](#)

Patterns Discovery

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Pedagogical Possibilities for the History of Computing

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Synonyms

[Classroom](#); [Historiography](#); [Innovation](#); [Syllabus](#); [Teaching](#)

The history of computing is a strikingly interdisciplinary field. It is not only that it joins two fields. What is more, the two disciplinary components, history and computing, are diverse in themselves. In addition, work in the history of technology is also conducted in an interdisciplinary manner, such as under the aegis of gender studies or science and technology studies. This provides many pedagogical opportunities for approaching history of computing in the classroom. An overview of these approaches can be garnered from professional associations and online syllabus repositories (SIGCIS 2018). Although this seems to result in a bias toward US courses in English, it does

seem as if until recently this topic was most often covered in a US context.

This article begins with a review of courses offered in the history of computing. The trajectory of the field and the STS lessons points the way to future directions. Following this, overview is a list of pedagogical best practices. The field known as science and technology studies (STS) offers suggestions to avoid pitfalls of developing classes of this type.

Overview of History of Computing Courses

It is not surprising that histories of computing in the classroom vary depending on the goal of the program offering the course. Accreditation standards also play a role. A brief overview of the progression of history of computing classes demonstrates how they have changed to meet the needs of various constituents.

Evolution Not Revolution

The earliest courses in computing often had at least a portion of the curriculum devoted to the history of computation tools. This history had various purposes. One was a way of attracting more people to the field by showing how important computation was to society. Another was to suggest that computers were really not as novel as they might seem. In an effort to create the impression that computers were calculating tools like

any other, these courses covered in broad strokes the history of computation to show that they were not mysterious. This effort took place in the context of the first computer science programs, which were housed in departments of mathematics or sciences and served an agenda of legitimizing the study of computation as a separate concern.

For instance, in 1958 at Concord High School in Massachusetts, educators offered an advanced mathematics course for high school seniors. The course included information about the history of computing tools and number systems in general, as well as providing awareness of current and future progress in computing. The course impressed upon students the idea that the main change brought about by computers was that they were more flexible than the earlier tools that were used. The course included instruction on using slide rules as well as a demonstration of how to calculate a rocket's trajectory with a computer at MIT's Lincoln Laboratory.

One of the first courses in the history of computing at the university level was taught in 1975 at the University of Kansas, Lawrence by Walter Sedelow, a sociologist who had worked at System Development Corporation (SDC, a company founded to work on the SAGE missile defense system, an early computing project) and the United States' Advanced Research Projects Agency (ARPA, a US government agency that was an early promoter of computing and created ARPAnet). The professor used his experience at SDC and ARPA to lecture about contemporary topics, including J. C. R. Licklider and computing at ARPA.

Another example of early offerings in the 1980s was by historian William Aspray, who was at Harvard for 1 year in his early career. He offered a first-year seminar and later a full course from a business perspective called "The US Computer Industry." In addition, Brian Stuart offered a course on the history of computing hardware at Rhodes College. In this class, students wrote and ran code for a restored PDP-8 and for an ENIAC emulator. Thomas J. Bergin began teaching a history of computing course at American University in 1988. As he describes it, students in other

programs had insightful courses about the history of the profession they sought to enter, and he believed the same would be helpful for computer science students. Bergin would go on to coauthor a book on the history of programming languages in 1996. These snapshots show that there was a variety of approaches to incorporating history into computing from the very beginning.

Accreditation standards helped the history of computing gain an academic foothold. ACM's Curriculum 78, for instance, recognized that social and ethical issues in addition to technical challenges should be considered by professionals when making computer applications. This stance was reiterated by the Computer Science Accreditation Board in 1984. The requirement could be fulfilled, according to accreditors, with a standalone, upper-level undergraduate course along the theme of computers and society. This course, according to the guidelines, could have a history component. This would encourage a curriculum that asked for social science models to understand how computers impact society, legal issues, and the public perception of computing. Because it was a separate course, it could be taught by faculty with a humanities or social science background, leading to an institutional pull for supporting this kind of work at universities that had accredited computer science departments. Later, the ACM/IEEE Computer Society published its Computing Curriculum 2001 standards which mandated historical coverage in several courses as well as exposure to social and professional issues and their historical context. This encouraged computer science programs to reach out to colleagues in other fields, either for advice or instructional support.

History of computing entered the university at a time when the history of science and technology was undergoing something of a sea change. An often-cited article, "Should the History of Science Be Rated X?" (Brush 1974), noted that science and engineering were not the isolated, objective pursuits they purported to be. This new thinking about science and technology meant that it could be subjected to historical analysis. Historians started to notice that scientists operate

subjectively, and so historians must do more than document solutions to scientific or technical problems. An historian “must be prepared to analyze the philosophical, psychological, and sociological aspects of scientific work, to explain how . . . particular standards happened to be accepted for evaluating solutions,” Brush wrote. This insight was particularly important in the history of computing and history of technology more broadly, where a multitude of solutions could be proposed to any particular human challenge. The choice of one particular solution based on its perceived fit with ideological, economic, or political goals is not an objective statement about the solution’s value but a subjective choice like any other choice an historical subject faces.

Thomas Kuhn (1962) had already proposed that there was more than objective fact behind the development of scientific theories. In *Structure of Scientific Revolutions*, he pointed out that there were many complications to the notion that the Earth was not the center of the universe, and so scientists had to account for the development of scientific ideas “in terms other than those of linear progress from error toward truth.” This nonlinear development would become even more relevant to technological devices like computers. It was in this context that the AFIPS started the academic journal *Annals of the History of Computing* in 1979. The original editorial board was made up of scholars who had expertise in computer science and included, at least in its earlier years, commentary and memoirs from those who had witnessed momentous events.

There were several textbooks used for these early courses, and the list shows the diversity of the approaches taken by the instructors. The primary texts were historical overviews like *The Computer from Pascal to von Neumann* (Goldstine 1973); the author was a collaborator of John von Neumann, the polymath who was a pivotal figure in the early days of programmable computing. Another widely used text was *A History of Computing Technology* (Williams 1985); the author was the instructor of a course at the University of Calgary. *The U.S. Computer Industry* (Brock 1975) was also frequently used.

Professionalization

In the 1990s, some courses relevant to this survey appeared in history or interdisciplinary departments, such as at the Illinois Institute of Technology, Stanford University, and the University of Manchester. Some of the current themes of history of computing courses are seen then, including women and computing. A majority of the courses were offered by computer science departments because they had a primary audience of computer science students who needed technical expertise at that same time they were expected to understand the historical, ethical, and other issues by accreditors. Some of these courses also had the aim of helping computer science students develop professional skills like writing. These courses appeared at Virginia Tech, the University of Calgary, Purdue, Swansea University, Georgia Tech, Eastern Michigan University, the University of Warwick, American University, and Princeton, among others.

The courses in the 1990s continued to be varied in their approach. Some, like courses at Virginia Tech taught by John A. N. Lee and at Swansea University taught by John Tucker, were general professionalization seminars that included information about the history of the field to convey the trajectory of their profession to students who were on their way to becoming practitioners. These asked students to conduct research reports to hone their communication skills. Convincing women to return to computing was a concern on the 1990s, and so courses like Jon Agar’s course at Manchester University included female figures in their curricula to help recruiting.

Other courses were part of the general education, offered wholly or in part outside of a computer science department. One was a joint project at MIT between the departments of computer science, electrical engineering, and science and technology studies. Spearheaded by David Mindell, this course sought to help students understand engineering practice better. Through case studies from history about a technology, company, or individual, students were introduced to vital issues like teamwork, oral presentations, and critical thinking. In 1994, Paul Edwards taught a

history of computing course at Stanford that was cross-listed as an introductory computer science course. This course sought to demonstrate the complex interactions between innovation and society in their historical context. Similarly, Michael S. Mahoney, a professor of history who had earlier expressed interest in the history of mathematics, offered a first-year seminar at Princeton in 1997 called *The World of the Computer*.

Some professors added articles from the *Annals* to their courses, along with new textbooks that had become available. Those interested in the use of primary sources could refer to a book like *Charles Babbage: On the Principles and Development of the Calculator and Other Seminal Writings* (Morrison et al. 1961). Computers and society were covered by books like the anthology *Social Issues in Computing* (Gotlieb and Borodin 1973) and *Hackers: Heroes of the Computer Revolution* (Levy 1984). A book about the prehistory of computers was *Reckoners: The Prehistory of the Digital Computer* (Ceruzzi 1983). Business history was offered by *Fire in the Valley: The Making of the Personal Computer* (Freiberger and Swaine 1984). Books about hardware were *Alan Turing: The Enigma* (Hodges 1983) and *Bit by Bit: An Illustrated History of Computers* (Augarten 1984). Various combinations of these texts appeared as required reading on syllabi in the 1990s.

For many years, John A. N. Lee at Virginia Tech was a proponent of including history, ethics, and other humanities or social science material in the computer science curriculum (Aker and Aspray 2004). This led him to create a large repository of Web pages that could be used for teaching such courses or for offering online versions of them. Lee, who had been chair of the International Federation of Information Processing (IFIP) Technical Committee 9 for the Social Impact of the Computer, used the opportunity to explore how making material available on the Web could impact teaching on history and other subjects. By 1997, his resources totaled over 3,000 pages. Due to the many courses required for the computer science degree, one

approach Lee advocated was that a part of the so-called humanities requirement offered outside the computer science department be tuned to the history of computing. Lee, along with Williams, John Impagliazzo, and Martin Campbell-Kelly, collaborated on a report published in the *Annals* (Impagliazzo et al. 1999) to encourage such a history course explicitly designed for computer science students.

Turn Toward Informatics

Toward the start of the new millennium, there was an increasing interest in studying applications of computers in other fields, often under the rubric of informatics. Although computer science had largely won its battle to become a separate discipline, this had been accomplished by applying tools of mathematical and scientific rigor to research. Not all uses of computing, it became clear, involved scientific research even though they were demanding in their own ways. Informatics, a new form of academic discipline that considered computation and society more generally, began to appear.

The trend toward informatics resulted in various outcomes. A 1999 course at Rensselaer Polytechnic Institute by Kim Fortun is illustrative because it started with the ideas of the book as an information tool. The course “IT Revolution – Myth or Reality?” sought to demonstrate how IT is innovated and how a student can become an innovator. The course required students to interview an IT researcher, and it included professional goals like requiring students to use gender-neutral language. At Indiana University in Bloomington in 2000, Mehmet M. Dalkilic offered one of the first courses in informatics, demonstrating how technology and people work together and how information works in business. His goal in covering the history of how information is stored and calculated was to think about constraints.

Another offering of this type was about the history of software. In 2003, Michael Mahoney at Princeton offered a new course “The World of Software,” partly based on his interest in system software but also reaching into bioinformatics, gaming, hypertext, and other applications outside

of computer science. Christopher Kelty offered a special topics course at Harvard University in 2007.

The expansion in the variety of computer history classes was aided by ABET's Curriculum 2001, which required that undergraduate students spend a total of 16 h on social and professional issues. This requirement included history, but it also suggested other topics that were amenable to historical approaches, such as ethics, privacy, civil liberties, and so on. In many cases, this led to the development of specialized courses taught by professionals in the humanities and social sciences, whereas before these topics could more easily be incorporated into computing courses.

A new generation of history books supported this turn toward informatics. Perhaps preeminent among them were *Computer: A History of the Information Machine* (Campbell-Kelly and Aspray 1996) and *The Virtual Community* (Rheingold 1993). Other books also appeared on syllabuses at this time, like *Crystal Fire: The Birth of the Information Age* (Riordan and Hoddeson 1997) and an anthology, *A Nation Transformed by Information* (Chandler and Cortada 2000).

It was in this context that new books suitable for college courses and research about software also emerged. *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry* (Campbell-Kelly 2003) is probably the best known. There were also books for the popular press like *Go To: The Story of the Math Majors, Bridge Players, Engineers, Chess Wizards, Maverick Scientists and Iconoclasts – The Programmers Who Created the Software Revolution* (Lohr 2001) and the proceedings anthology *History of Computing: Software Issues* (Hashagen et al. 2002).

Several academic books with a broader scope were also offered by MIT Press, such as Ceruzzi (1998) *A History of Modern Computing*. In this text, Ceruzzi focuses primarily on the development of hardware in the US context. Janet Abbate (2000) *Inventing the Internet* focuses on networking, starting from experiments in packet-switched networks in the 1960s through the development of the WorldWideWeb application in the 1990s.

Abbate also focuses on a primarily US context. Milton Mueller (2002) *Ruling the Root: Internet Governance and the Taming of Cyberspace* combines policy and economics with computer history to understand innovation better.

In the 1990s, computer science departments saw a renewed attention to recruiting students and faculty from traditionally underrepresented groups, particularly women, to the profession. Accordingly, at the start of the new millennium, new work was published for use in college classes to understand the interactions between gender and technology. Representative texts are *Unlocking the Clubhouse: Women in Computing* (Margolis and Fisher 2002) and *When Computers Were Human* (Grier 2005). These books were typically assigned to support a portion of a course that was related to diversity.

Computers and Society

Perhaps bolstered by the broader definition of computing offered by informatics, the start of the twenty-first century saw a widening of the types of courses that provided insight into the history of computing. It is not as if the types of courses outlined above were discontinued, however. To the contrary, there continued to be introductory computer science courses that included a history component, history of computing courses that sought to introduce professionalization, and so forth. In addition, there was greater attention from a variety of disciplines that used the history of computing in a new context. At the start of the twenty-first century, a place in computing for more everyday individuals had been secured, and professors from many disciplines turned their attention to the field as they would any other growing phenomenon.

As before when considering a new development, professors sought an historical context. Accordingly, an examination of historical narratives are found in a variety of computing and society courses in various disciplines, even those not expressly devoted to history. At the University of Namur in Belgium, for instance, a 2002 course by Marie d'Udekem-Gevers was given on the theme of anthropological approaches to information,

“Approche anthropologique de l’informatique.” In 2004 at Brown University, Roger B. Blumberg offered a first-year seminar that put computing ethics into an historical context, thinking about utilitarianism and republican ideals as well as the history of the concept of human nature.

Courses were also offered to connect the history of computing to a larger social context. Abbate offered a course on internet and governance in 2008 as an STS course at Virginia Tech. Bernard Geoghegan offered a course on computers and globalization at the American University of Paris that same year. Courses inflected by business history were also popular. Michael Mahoney, in 2007 at Princeton, taught a history of computing course that was heavily influenced by business history. At the University of Pennsylvania in 2009, Nathan Ensmenger expressly reached out to humanities and social science students and crafted a history of computing course that used computing technology as evidence of wider human activities, like management and labor. These courses depended upon the discipline of computing history to varying extents, but they sought to expand the audience for the field.

These interdisciplinary voyages into the history of computing were inspired by and also supportive of new studies. For instance, a popular management-side study *Where Wizards Stay Up Late: The Origins of the Internet* (Hafner and Lyon 1996) offered a journalistic account of the managers who brought together ARPAnet that is still referenced 20 years later. *The Social Life of Information* (Brown and Duguid 2000) came from a business perspective to show how companies add value to information and, instead being threatened by a new paradigm, would show the way to the future. *The Dream Machine: J.C.R. Licklider and the Revolution that Made Computing Personal* (Waldrop 2001) similarly came from a management perspective to show how the dream of interconnected research centers evolved into the personal computer. Manuel Castells (2001) *The Internet Galaxy* offered to managers a philosophy of the Internet and mused on how it would change culture and business. These texts often appear in the syllabi of courses in the early 2000s.

From a social history standpoint, *What the Dormouse Said: How the Sixties Counterculture Shaped the Personal Computer* (Markoff 2005) offered a different type of history, suggesting it was counterculture, and not business culture, that produced the personal computer. This theme is also explored in *Bootstrapping: Douglas Englebart, Coevolution, and the Origins of Personal Computing* (Bardini 2000) and *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism* (Turner 2006). As a counterpoint to the institutional histories, these books were used in college courses when instructors want to remind their students that the ideals of collaboration and counterculture were important forces in the development of computing.

Books from a variety of other disciplines also start to be seen in syllabi at this time. Legal studies was represented by *Code and Other Laws of Cyberspace* (Lessig 1999), which shows how important concepts like the commons are behind the transformative power of computing. An influential media studies book often seen on syllabi was *Remediation: Understanding New Media* (Bolter and Grusin 1999), a book that takes an historical look at the transformation of content when it is transferred from an old to a new medium. These texts were used in courses when professors sought to show how what seemed to be new in computing actually had historical precedent.

Several books from the perspective of literary studies also began to appear in discipline-specific contexts. *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Hayles 1999) put contemporary fiction and philosophy into its historical context to suggest that we have always been posthuman. A poetic reflection on Vannevar Bush and the origins of personal computing, *Othermindedness: The Emergence of Network Culture* (Joyce 2000) considers how computing is shaped by a historical imagination of information. Lev Manovich (2001), in *Language of New Media*, grounds his analysis of the forms of computing in their historical roots in media. Courses in the humanities that used to these books sought to ground computing in the disciplines in its historical context.

Limitations of Master Narratives

The profession of history in general has been distrustful of metanarratives since at least the 1960s, and the idea of one universal history for all people at all times has been long derided by historians of many types. Although US professors dominated the earliest forays into the history of computing and, lacking a tradition, it seemed necessary for them to first craft a standard history of computing from the perspective most relevant to students in U.S. universities, there was no reason that telling the history from other perspectives was impossible. This change came about when professors outside the USA began to consider national histories. A series of four workshops from 2003–2014 sponsored by the International Federation of Information Processing's Working Group 9.7 on the history of computing, for instance, focused on Nordic computing and its workshop in 2006 focused on Soviet and Russian computing. These demonstrated the potential of this opportunity. Classes in the past 10 years have started to show revisions and resistance to one standardized history of computing.

A book translated from the French, *The Universal History of Computing: From the Abacus to the Quantum Computer* (Ifrah 2002), began to appear in courses at this time. In spite of the word “universal” in its title; the book seeks to demonstrate the global and historical context for computing, showing that contemporary developments in computing are dependent upon a worldwide collaboration over many years to make automated calculation possible. *Networking Peripheries: Technological Futures and the Myth of Digital Universalism* (Chan 2014) makes this point more directly. *Cybernetic Revolutionaries: Technology and Politics in Allende's Chile* (Medina 2014) is used in courses because it shows how histories from outside the core institutions in the United States provide valuable insights into computing. *The Undersea Network (Sign, Storage, Transmission)* (Starosielski 2015) shows how communication networks before the Internet had much to say about the current development of global telecommunication; innovations do not remake the landscape anew.

Recent courses that reflect this interconnection between computing and the history of the globalized world are represented by Rebecca Slayton's 2010 course at Stanford, “Imagining the Computer, Wiring the World,” which uses some of the standardized history of computing but also covers the cultures that gave rise to transformations in computer history and their global consequences. In 2016, Paul N. Edwards offered “Computers and the Internet: A Global History” that intertwines international histories with the standard core history of development in the United States.

One problem with the standardized history of computing is that it reflects the notion that it was largely independent, male geniuses and only male-dominated institutions that were relevant to the history of computing. In Fall 2016, Marie Hicks turned the history around, telling it from the perspective of women in her course “Women in Computing History” at the Illinois Institute of Technology. In the same semester, Joy Lisi Rankin offered “Histories of Computing and Gender” at Lyman Briggs College. New books to complement earlier studies on syllabuses in this context are Abbate (2012) *Recoding Gender: Women's Changing Participation in Computing* and Hicks's (2017) own *Programmed Inequality: How Britain Discarded Women Technologists and Lost Its Edge in Computing*.

It is also clear that the standard history of computing focuses on new devices without considering the sourcing of the material used to build them or their environmental impact, such as the heat produced by server farms. This lack of attention has proven to be another opportunity for professors. In 2015 at the Victoria University of Wellington, for instance, a course entitled “Sustainability and Information Systems” was offered by Janet Toland. This course engages information management students in sustainable practices for information management, considering to some extent the historical case and the need for policy change.

Future Directions

It is no longer a question whether computer science is a viable field, given the large number of

computer science departments, and so it is no longer as imperative as it once was for courses to provide a history of computation in order to assert the importance or to make computing familiar. Nevertheless, professors continue to innovate how computing can be considered in its historical context. New directions are likely to follow innovations in the use of computing and architectures of computing hardware.

As increasing attention is given to new topics in computer science, one would expect for there a similar variety of courses to be offered as was seen for the history of computing more generally. As suggested by this overview, the first attention to history of a new topic will be given within computer science courses themselves to provide a familiar starting point for students. Then, in the computer science departments, courses about history (that sometimes falls in line with concerns of ethics or professionalization) will be offered, and then specialized courses offered by humanities professionals (either in computer science department or in humanities departments), as well as outsiders in a variety of humanities or social science fields, will be developed.

This is seen in recent courses in artificial intelligence, which require students to think in new ways about programming. Current textbooks offer a brief overview of these topics in the same way that general computing courses once did. A recent book, *Prehistory of the Cloud* by Tung-Hui Hu (2016), points out that the seemingly new phenomenon of cloud computing is built on an existing telecommunication infrastructure. New developments can be covered academically in fairly predictable ways. In support of her university's new interest in gaming, for instance, Laine Nooney offered a course, "Video Games: Culture and Industry," that put computer gaming into its historical and analog contexts at New York University in 2014.

As artificial intelligence, gaming, hardware security, cloud computing, and the Internet of Things become increasingly important areas for the innovation and use of computing, new pathways through the history become apparent. In the same way that early computer history courses showed the many ways in which the forerunners

to computation were essential to society, future courses in the history of computers will be needed both to demystify new devices, recruit students to emerging fields, and help the general population understand them. Courses about the history of security to support cyber- and hardware security, the social and legal history of privacy to help evaluate computer privacy, the development of schema for modeling intelligence to enhance the innovation of artificial intelligence, and the history of the built environment for context of the Internet of Things will play important roles in college courses to come.

The trend for localized histories of computing will also be of increasing importance in the future. As many countries come to terms with computerization and the consequences of technology, it will be important for college classrooms to craft national histories that recast the standard history into local terms. These histories will, in turn, help to revise the standard history in a way that better reflects the international scope of computing.

Potential Pitfalls

There are several potential pitfalls with respect to history of computing curricula that might not be obvious to someone who is a member of one of the component groups of this interdisciplinary field. Two of them are a reliance on so-called whig history, and the other is technological determinism.

Whig History

One common complaint from science and technology studies practitioners are histories that employ what is known as a "whig" perspective. This is a term borrowed from British politics. One can imagine a member of the conservative Whig party telling a story of how the present state of affairs came about inevitably, leaving no alternatives. In the history of technology, a whig history suggests that the present moment has come about from an inviolable series of technological advances.

An historical approach based on a whig history is one where there were not branching paths or

alternatives in the development of technology. In other words, technological progress is cumulative without sidetracks or multiple possibilities. When telling a whig history of technology, it seems as if the merits of an idea alone determine whether it will be successful and that the best idea always is successful. Apparently, there were never any errors, misunderstandings, or challenges to good ideas. In a whig history, advantages that come from alliances with existing economic, political, ideological, or legal institutions are ignored. What happened had to happen in the way it happened, and there were no alternatives that could have come into being had they gained greater credence.

This appellation came in the 1930s from outside the history of technology by Herbert Butterfield to decry English constitutional historians, in telling of the forward-looking liberals struggling with conservatives. History in this sense is presented as a progressive force, with all developments leading up to the present moment and projecting a path into the future. In the 1970s, the term came to be used by historians of science as a caution against those who would suggest that the past reflects present concerns, with the result that anyone who does not accept the supposedly inevitable path toward modern ideas is not using the correct analysis. Historian Donald Cardwell (2003) took up this problem in his essay "Reflections on Some Problems in the History of Science," where he notes that each age thinks about science differently, and as well, each age has a different idea of what history itself is. Thus, it is impossible to think of "autonomous histories" of science, reading backward into earlier discoveries to prove that each was a stepping stone to the present. While the doctrine of progress is compelling, he goes on, it is not the case that everyone who did not work toward the present understanding is a fool.

Historians should be able to account for more than one path, Caldwell says, but also should not believe that all matters of importance have already begun to be solved and it is the task of the future simply to "tidy up the ends." Endowing science with a progressive force of historical inevitability, Caldwell says, shuts off the critical mind. In education, this will inhibit innovation because it is not

as if great ideas were "handed down by some celestial text-book writer to whom there were immediately self-evident." Whig versions of history are helpful when the pedagogical goal is to make problem solvers who work within accepted paradigms. For innovators, a history of the contingent is necessary.

Sociologist Bruno Latour is often invoked to combat the simplistic thinking behind whig history. In *Pasteurization of France* (Latour 1988), for instance, Latour notes how competing methods of public health were defeated when Pasteur found an alliance with the clean streets model of public health. In other words, it was not the veracity of his invention that caused it to be adopted, but in fact his ability to make an analogy to a popular movement even though it did not support his science. In the realm of technology, Latour writes *Aramis* (1996), a "scientifiction" of a public transportation system in France that failed to be constructed. In his personification of Aramis, Latour describes how a plausible system that passed its feasibility tests failed to gain a foothold in the imagination of politicians and the public in order to be built. These texts show how actor-network theory offers an alternative to the smooth, steady progress of technology.

Technological Determinism

Technological determinism must be avoided when teaching the history of technology. A technological deterministic analysis suggests that culture is inevitably transformed by using a technology, and this is often used to prescribe a policy proposal. For instance, one might suggest that using computers must inevitably make people more democratic, and so distributing low-cost computers will inevitably increase free thinking.

Using the development of the television as an example, Raymond Williams (1974) has pointed out that determinism is a fallacy because visions about what a device can do precede the technical capability to make it happen. Visions of using television were quite different than what was actually the use in practice. What is more, he points out, the same device was used in different ways in liberal and authoritarian countries: as a

consumer good for families in the former and as a tool for neighborhood viewing in the latter. Although a device must exist, to some degree, in harmony with the ideology that surrounds it, it does not determine changes to the culture independent of history, economics, law, and so on.

Sally Wyatt (2007) has suggested the intellectual habit of naming historical periods for their dominant technological devices is a form of reductionist thinking dependent on technological determinism. She reminds us that technological devices are not invented outside the societies in which they are used, and that devices cannot unilaterally transform them. This obviates human choice, she says, and more importantly it absolves humans from their abuses. She suggests that this attitude is helpful for the purveyors of new technologies because workers and consumers are then seen as powerless to criticize the use and consequences of technological choice.

One way to refrain from determinism is to recognize that technologies are socially constructed. Science and technology studies scholars, like Bijker et al. (1987), have offered the example of the invention of the bicycle to explain how this process is different from determinism. It is impossible, they write, to look back in time and find a moment when the bicycle was invented because there were many contemporary designs for what a bicycle could be. A determinist interpretation would seek to find the essential characteristics of the present design in the past, but a constructivist asks a different question: how were the various designs seen as separate from each other, and why was it that a particular set of design choices come to be known as the obvious and natural default design for a bicycle? In understanding how a competing set of acceptable alternatives were winnowed away into one naturalized design, one can see how social groups and other imperatives play a role in technical development. It is not as if one design was best, or that one design was demanded by one unified market. Instead, the solution that was successful was the one that fit in best with the overall social and economic system.

Cross-References

- [Computing Curricular Report IT2017, A Summary](#)
- [Rationales for Information Technology in Schools, Historical Perspective](#)
- [Why Teach History of Computing?](#)

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Policy Rationales and Integration Rationales, Implications for Subject Area Teaching

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Over the past three decades, the number of national educational policies addressing technology integration in teaching and learning has significantly increased. Rationales for these policies have largely reflected the perception that the world is more technological and to raise the quality of national workforces schools must prepare students to compete in a knowledge economy (Kozma 2008). The problem is that these national aims do not translate to technology integration in teaching and learning (Hammond 2014). As a result, high-level educational technology policies often will have limited impact on teachers' practice and student learning.

One of the key reasons for this problem is a lack of alignment between national educational technology policy and curriculum. The recontextualization of educational policy to the classroom is largely a political rather than educational practice, which is often driven by a social agenda rather than teaching and learning. As such, rationales for technology education policy are often oversimplified, which often makes them unattainable in practice. As such, policy often treats digital technology integration as a homogenous practice, which does not address the specifics of learning and teaching in subject and learning areas (Howard et al. 2015a). "Teachers accept or resist particular reforms according to . . . their academic subject orientations and commitments, and their school's identity" (Hargreaves and Goodson 2006). However, policies are unlikely to address the processes of technology integration and teacher change or make explicit connections to teaching and learning (Levin 2008). Schools and teachers will often feel unclear about how they should engage with expectations of educational policy, while ensuring that students are

meeting learning expectations and subject curriculum outcomes. Therefore, a disconnect between policy and classroom integration is often present, which affects the overall impact of educational technology policy.

This article will address educational technology policy rationalizations and how they are recontextualized within educational systems and aligned with teaching and learning. Further, it will discuss how educational policy enables and constrains technology integration in teaching and learning and problematizes teaching in specific subject and learning areas. Progress in this area will be discussed.

Educational Technology Policy

Internationally, it is relatively agreed that use of digital technologies promotes social, economic, and educational change and innovation. The importance of information and communication technologies (ICTs) in peoples' daily lives, in business operations, and in education is accepted internationally. The Organization for Economic Cooperation and Development's (OECD) Programme for the International Assessment of Adult Competencies (PIAAC) (OECD 2017b) and the Programme for International Student Assessment (PISA) (OECD 2017a) both include repeated measures for adult and students' numeracy, literacy, and problem-solving in technology rich environments. The PISA studies in 2003 and 2012 explicitly addressed students' capacity to use digital technologies, stating that ICTs "have revolutionized virtually every aspect of our life and work" (OECD 2015). Results from these tests are used in both developed and developing nations to guide educational technology policy.

The current OECD outlook for future work is that automation and computer intelligence will play a large role, and those not prepared for such changes will suffer limited prospects (Elliott 2017). Helsper and Reisdorf (2016) and other researchers in the area of digital inclusion have long stressed the association between the effective use of technology and future inclusion and

participation in society. Those that are not able to harness digital technologies will not flourish in future society. Recommendations such as this guide national social, economic, and educational policy development. They provide countries with strong rationales for national educational technology investment and initiatives.

National Policies

The World Bank (2017a) has stated that “with globalization, the information revolution, and increasing demands for a highly skilled workforce, nations are increasingly prioritizing education” (para 1). However, decision making about how to do this is often inconsistent. Government agendas shape educational policy, but agendas are influenced by social and political pressures (Connelly et al. 2007). Using publications such as these from the OECD, individual nations can decide how they will prepare young people for this future, through creation of relevant educational technology national policy. For example, consistent social pressure to motivate the creation of national ICT education policies, such as Singapore’s ICT Masterplan (Singapore Educational Technology Division 2015c) and Australia’s past Digital Education Revolution (Department of Education Employment and Workplace Relations 2012), are required. Both of these policies are driven by the rationale that young people need to be prepared to compete in current and future global societies, but they address the issue in different ways. In Singapore, the policy was first implemented in 1997 “to enrich and transform the learning environments of our students and equip them with the critical competencies and dispositions to succeed in a knowledge economy” (Singapore Educational Technology Division 2015d). In 2015, this focus was specifically to promote “teachers as designers” and “school leaders as culture builders” (Singapore Educational Technology Division 2015e). In Australia, the policy was more about infrastructure; providing computers and broadband connections to schools, the logic being that having a personal device would promote students to have the types of competencies needed to be competitive in future work and learning. Both of these policy initiatives are based on the idea of developing twenty-first

century competencies, which were strongly supported by the OECD (e.g., OECD/CERI 2008). These represent some of the complexities addressing educational technology, where two very different approaches to technology integration come from the same rationale.

To help policy makers navigate ICT in education, The World Bank created the *Systems Approach for Better Education Results* (SABER; The World Bank 2017b). This tool provides support for policy makers in “assessing and benchmarking their own ICT-in-education policies against those of comparable countries around the world” (The World Bank 2017b; para 1). One of the key reasons for using benchmarking as a way to address educational technology policy, as outlined by The World Bank, is that there is little accessible data showing impact of ICTs in education. While there is clear consensus about *how* digital technologies are used in work, there is a lack of evidence about the benefits of using and *why* digital technologies should be used in teaching and learning. This has complicated development and implementation of educational technology policy and is part of the reason why there is a disconnect between the policy and integration in the classroom.

Policy Rationales

The development of national educational policy can be divided into two approaches: strategic and operational (Kozma 2008). Strategic policies will often act as a tool to motivate and stimulate change to address a nation’s overall educational goals. National educational goals are often based on high-level needs of society, such as an improved work force for the future and producing better educated citizens. Common rationales for strategic educational technology policies have been preparing citizens for “future work” in the United Kingdom (e.g., Department for Digital Culture Media & Sport 2017), increasing participation in a knowledge-based economy (e.g., EU Science Hub 2017), creating democratic access to learning for all individuals (U.S. Department of Education 2017b), just to identify a few. Strategic policies provide a future vision and direction for ICT initiatives and justification for funding

necessary to make it all happen (Kozma 2008). Therefore, they are by nature high-level broad goals and have tended to be oversimplified (Hammond 2014).

The second type of educational policy, operational, are where strategic policy visions are realized. They will often have a more pragmatic focus, such as setting up programs and resources to support change in relation to national educational goals. In many cases, this type of policy will be tied to a strategic policy. Therefore, it is likely to have a more direct connection to implementation at the state, district, or school level. An example of this is the national “Funding Digital Learning” (FDL) program in the United States, which is linked to the strategic National Educational Technology Plan (NETP; U.S. Department of Education 2017a). The strategic NETP vision of technology in education is one of “equity, active use, and collaborative leadership to make everywhere, all-the-time learning possible” (para 1). Good connectivity and infrastructure are key aspects, as outlined in the NETP, to make “all-the-time learning” possible. The FDL program is designed as an operational approach to provide funds to purchase digital or related resources for states and districts to fulfil NETP aims. The rationale for the FDL program is to support technology upgrades, to keep pace with technological change, and improve instruction and student outcomes. The FDL represents a particular approach to help district and state leadership realize that aspect of the national plan.

Considering Singapore’s ICT Masterplan again, the realization of this policy illustrates the connection between strategic and operational policies. The Masterplan is now in its fourth version (Singapore Educational Technology Division 2015c). As stated earlier, it is a strategic policy based on the rationale that it is necessary to put “quality learning in the hands of every learner – empowered with technology” (Singapore Educational Technology Division 2015e). This policy is operationalized through four “approaches”: (1) deeper ICT integration; (2) sustained professional learning; (3) translational research, innovation, and scaling; and (4) connected ICT learning

ecosystem (Singapore Educational Technology Division 2015a). Each of these approaches have a number of individual priority areas, which are addressed through specific programs or initiatives. A specific element of this is the operationalized policy Cyber Wellness, which is part of “Deepening Digital Learning” in Approach 1. The rationale for this is the importance of internet users having positive well-being and that it is a necessary aspect of appropriate technology use in teaching and learning (Singapore Educational Technology Division 2015b). This has been realized in part of the Singapore ICT Connection website for teachers and students to access.

These examples demonstrate how broadly defined educational technology policy is implemented within an educational system. The process of translating and operationalizing a strategic policy requires recontextualization. This means that policies are interpreted to suit values, needs, and requirements of a given context. The process of recontextualization changes the intent and goals each time the policy is translated to a new part of an educational system. Depending on the context and the nature of the policy as it is operationalized, it may result in good (meaning matching values, needs, and requirements) alignment between the policy and the context or not. If not, the policy is likely to lack impact.

Policy Alignment

The assessment of alignment is one of the ways policies can be analyzed to determine its impact, but also a way to identify where policies need reconsideration. Policies can be evaluated for horizontal, vertical, and strategic-operational alignment (Kozma 2008). “Horizontal” alignment relates to compatibility of policy goals and other policies in a system, such as curriculum and teacher training. “Vertical” alignment is the coordination of policy between different levels of an educational system, such as agreement between the state, district, or school levels. Alignment in these two areas ensures that resources are appropriately allocated across a district and in schools, but also that policies are working efficiently and not duplicating other efforts.

“Strategic-operational” alignment refers to how well operational policies support national goals and rationales.

The alignment of a strategic policy with the realization of operational policies at a school and/or classroom level is significantly affected by the nature of an educational system, distance of implementation from the original national goal, and the context. It has been argued that alignment between national policy rationales and implementation of technology integration in teaching is not possible (Hammond 2014). One of the reasons for this is that educational technology policies are unable to fulfil the driving rationales, as digital technologies are unlikely to have a significant impact on teaching and learning themselves. Where digital technologies do affect learning and teaching is difficult to measure.

Policy and Technology Integration

The “disconnect” between educational technology-related policy and digital technology integration is well known. After several decades of educational technology policy, digital technology integration continues to be inconsistent within and between schools (Perrotta 2013). As highlighted earlier by The World Bank, there is a lack of evidence guiding leadership and teachers on how to best use digital technologies in schools and for teaching and learning. For teachers, integrating digital technologies in teaching represents a considerable change in practice and how they conceptualize learning, which has proven to be difficult. This is compounded by ongoing educational technology policy change in education resulting in change fatigue (Orlando 2014), lack of principled understanding of technology integration, and how it can be best used to support learning in their subject and learning areas (Howard and Maton 2011). Thus, schools and teachers are often unsure how new technologies will affect learning, if curriculum and assessment expectations can be met, and how to fulfil policy goals and rationales.

A Case Study

To explore how issues of policy alignment enable and constrain technology integration in a

classroom, a case study will be examined. The case study is the Australian Digital Education Revolution (DER), which was an Australian national strategic educational technology policy and part of a government education reform agenda. The underpinning rationale for the DER was that all states would receive funds: “... to achieve technology enriched learning environments to assist students to achieve high quality learning outcomes and productively contribute to our society and economy” (The Commonwealth of Australia 2009). It was initiated as a political campaign promise in 2007 and was implemented from 2008 to 2013.

The aim of the DER was for all schools to achieve a one-to-one student-to-computer ratio by the end of 2011. This national strategic policy was operationalized through three other policies. First was the provision of money to states, which is the next level down in the Australian educational system, through the National Secondary Schools Computer Fund (NSSCF). The aim of this funding was to increase students’ access to digital technology, to achieve a one-to-one student-to-computer ratio across the country. The second approach was to fund High Speed Broadband to Schools for installation of “fibre-to-the-premise”, to provide all schools with a high-speed fibre optic internet connection. The final policy was the Digital Strategy for Teachers and School Leaders initiative to fund support for teachers’ ICT professional development (Digital Education Revolution program – National Secondary Schools Computer Fund 2011).

Initially, the DER program was administered from the federal level to schools directly, through an application process. However, this became too difficult to manage and maintain accountability. Funding was then transferred to the states through a National Partnership Agreement and then distributed to schools. An audit of the program reported that by mid-2011 schools had not achieved the one-to-one ratio. Many were at 1-to-1.3 to 1-to-1.25. The audit also reported that school principals felt that the impact on teaching and learning was positive (Digital Education Revolution program – National Secondary Schools Computer Fund 2011, para 17–18). A state evaluation of the program told a different story. In one

state, all Year 9 (aged 14–16 years) students and teachers had a personal laptop, but a survey of state secondary schools showed no significant change in students' use of digital technology or a significant change in teaching practice by the end of 2011 (Howard et al. 2012).

The computers had been delivered to the schools through the NSSCF program and funds had been provided for professional learning through the Digital Strategy for Teachers and School Leaders. These represent two operational policies, related to the broader DER policy. These addressed access to digital technologies and teacher training to use the new tools in the classroom. However, the DER policy aim was to have “high quality learning outcomes” through the use of digital technologies. But at the time, there was very little structure provided from the national level to states about how to implement the initiative in their contexts. At the state level, little guidance was provided to schools and teachers on how to appropriately use the computers or what professional learning was needed to support the wider policy rationale. The reasoning for this at both the state and school level was to ensure autonomy of stakeholders to be able to enact the DER policy appropriately for their context. However, the lack of specificity on how to operationalize the policy goals and how to use the computers resulted in a range of alignment issues, which constrained integration.

Implications of Alignment

Using the DER example, it is possible to explore how educational technology policy may be enabled and constrained as a result of horizontal, vertical, and strategic-operational alignment. Specifically, the discussion will address the DER in New South Wales (NSW). NSW is one of the largest school districts in the world and chose to deliver a laptop to each Year 9 student (aged 14–16 years). Laptops were also provided to all full-time teachers. This program was evaluated between 2009 and 2013. Overall, the program was met with mixed reviews and with slow up-take across the state. Only after 4 years of having access to the laptops were significant changes in technology integration observed.

However, this change was inconsistent across schools and subject areas (Howard and Mozejko 2013). The following sections will consider why the policy did not result in stronger and more consistent impact.

Horizontal Alignment

In terms of horizontal alignment, the DER-NSW program was widely supported throughout the state and by the school department. Changes in state policy to support the DER included putting significant funds toward professional development to support teachers' technology use, such as providing face-to-face training, creating DER-specific online curriculum support and resources, having a Festival of Learning, and so on. Teachers were provided with a wide range of ways to engage in professional learning through the state education department. This suggests strong horizontal alignment between the policy and teacher training. Further, the state provided funds to increase technical support by placing laptop technicians in schools to support maintenance and management of the laptops.

However, there was a lack of alignment between the DER policy and learning, specifically the state subject area syllabi and national assessments. The subject area syllabi at the time did not include areas for digital work or integration, beyond including that students would use certain tools. For example, in science they used spreadsheets and databases. In mathematics, they used spreadsheets (BOSTES 2012). These uses tended to be quite straightforward and would not have qualified as the “high quality learning” desired as part of the national DER strategic policy. Feedback from teachers and students revealed a belief that the DER laptops were not needed for learning, particularly to do well on assessments. In many cases, the laptop was even seen as a detriment to learning (Howard and Mozejko 2013). Without technology integration as a priority in subject area teaching, curriculum, and assessment, horizontal alignment was not strong even with good alignment in other areas. This was a significant contributor to the policy having minimal impact on teacher practice and was of little benefit to schools (e.g., Kozma 2008).

Vertical Alignment

Vertical alignment of resources from national to state to school levels was visible and well managed. In many cases, teachers felt pressure to use the laptops because of the significant government investment, national policy, and availability of DER professional learning opportunities (Howard and Mozejko 2013). Research has shown that this kind of pressure can be a strong catalyst for teachers to adopt and integrate digital technologies in their practice (e.g., Zhao and Frank 2003). However, at the time of the DER, there was considerable fluctuation in the national government and significant ambiguity if national funding of the DER would continue, year to year. Moreover, the state did not commit to continuing the DER if national funding ceased to be available. This left schools and teachers with a feeling of limbo about the program and if it would continue. This significantly affected how much time and energy they were willing to invest in new teaching strategies and creating integrated lesson plans at the subject level (Howard and Mozejko 2013). Therefore, while there was actual strong vertical alignment, stakeholders perceived weak alignment resulting from a lack of government commitment, which impacted on their willingness to change their teaching practice and significantly engage in the DER program.

Strategic-Operational Alignment

The DER was fairly typical of large-scale government implementation of one-to-one computer programs, in that there were relatively clear connections between strategic and operational educational technology policies. Similar programs at the time were the Maine Learning Technology Initiative (Silvernail and Gritter 2007), Michigan Freedom to Learn (Lowther et al. 2012) program, and the Berkshire Wireless Learning Initiative in Massachusetts (Bebell and Kay 2010) in the United States. All of these programs were based on the rationale that increasing access to technology would also promote high quality learning through the use of new and modern tools. The three national DER operational policies provided explicit support to achieve the national goals by providing funding for computers,

infrastructure, and teacher training. This has also been the approach in other one-to-one programs. All three of these are necessary for technology integration to occur and for policy to have an impact on teaching and learning. However, this also reflects a historic trend of noncritical treatment of digital technology integration and a general assumption that use of technology will result in learning (e.g., Bayne 2015; Beynon and Mackay 1989; Hammond 2014).

Research has shown that there are gains in learning when digital technologies are used in the classroom, but there is very little understanding as to why or how this happens (e.g., Skryabin et al. 2015; Tamim et al. 2011). Effective uses of digital technologies are those that support teachers and students reaching desired learning goals (Tamim et al. 2011). Learning goals will differ between subject areas, as will conventions of teaching, the types of skills and content knowledge students must acquire, and their assessments. As little is known about how technology integration positively affects learning, there is even less understanding of how to connect technology integration to wider policy rationales and goals (Hammond 2014). Goals related to teaching and learning will naturally differ from those used as policy rationalizations.

The problem is that strategic and operational policies have tended to treat technology integration as a homogenous practice (e.g., Howard et al. 2015b). Little attention is paid to the specifics of teaching within subject areas and how learning goals are achieved, which has significant implications for the enactment of those policies. For example, in the DER, providing teacher training was one of the main operational policies. In NSW, that teacher training often promoted a student-centered and project-based approach to learning (Howard and Maton 2011). This aligned with subject areas such as English and history, less with science and it was at odds with mathematics (Howard 2011). Teachers who were not comfortable with using a student-centered approach in their classroom felt that digital technologies were not necessary for their teaching or were uncomfortable using computers. They would often make the argument “that’s not how we do

it” or “that’s not how we teach” in their subject area (e.g., Howard 2013). Therefore, while there may have been alignment between strategic and operational policies in the DER, both lacked alignment with teaching and learning. This resulted in the policy having little impact on teaching and learning, and even having a negative impact on teachers’ willingness to engage with technology integration.

Progress and Conclusions

It is known that students need to be using digital technologies in sophisticated ways to prepare them for future work and learning (Helsper and Reisdorf 2016). However, the complexity of educational change and technology integration makes it difficult to identify why many educational technology policies fail to have significant impact in education. In the example presented here, there are a range of areas that need better alignment, such as the dependability of resources to fund the DER program from national to state to schools, which constrained teachers’ willingness to engage in the initiative. However, what really matters to teachers in technology integration is learning (Ertmer and Ottenbreit-Leftwich 2010; Howard 2013). For many teachers, the conception of learning is within the scope of their subject area or the key learning area they are teaching. By and large, they will stay with their known and successful approaches to teaching and learning, rather than put learning at risk by using new digital technologies.

For policy rationales to be attained, stronger alignment with subject area learning goals is essential. This approach would increase alignment and create a direct connection between teaching and policy aims. As a step toward improving the impact of educational technology policy, many countries have started to embed digital literacy, medial literacy, and so on, in curriculum documents. In Australia, the Australian National Curriculum contains an Information and Communication Technologies (ICTs) General Capability. This provides a framework for what students need to know about and how they should

work with digital technologies (ACARA 2012). The operationalization of curriculum in state subject area syllabi creates a direct connection between learning goals and rationales for national educational technology policy.

Other areas of development, such as school leaders fostering a culture of experimentation and more personalized professional learning opportunities, are needed to support teachers in their own school contexts to integrate digital technologies. For example, while many teacher training options offered as part of the DER were focused on specific subject areas or teaching contexts, they were segmented from the classroom. Teachers need to test and trial new digital technologies in their own teaching, to adapt and pedagogize with their own students (Hammond 2014; Tondeur et al. 2013). Building this level of support at the school level, into operationalized educational technology policy, would strengthen alignment and improve the impact of policy in teaching and learning.

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Positioning Children with Digital Interactive to Enable Early Conceptual Learning

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Definitions

Positioning theory highlights that what learners can make of concepts is dependent on the support they are given. Digital interactives are representations using combinations of words, images, sounds, and symbols that can provide support for learner use of concepts by giving feedback or

requiring responses, action, or input from users as they interact those conceptual representations. Digital interactives are thus changing how children can be positioned with concepts, what concepts they can learn, and what young learners can do with those concepts.

Introduction

What children can learn is dependent not only on their age or what some see as their stage of development but, significantly, also on the resources the culture they find themselves in makes available to them and how they are positioned with those resources by their more experienced others. Today, toward the end of the second decade of the twenty-first-century talk of molecules, DNA, gene editing, nano-materials, black holes, the World Wide Web, and Google Earth are ever present. These ideas are facts of culture that are changing the everyday lives of adults and children alike in our ICT-rich world. Such material resources can influence what can be considered intuitive for young children. What they make of these ideas is dependent on the support they are given to make use of the resources – how they are positioned with the ideas.

As Google turns 20 years old, in 2018, adding digital tools to the bank of resources shared with young children is not, as yet, commonly accepted practice in the early years. This is so despite today’s virtual reality digital tools putting the Earth, and other “abstract” concepts, at their fingertips in everyday life, figuratively and literally. Such interactive artifacts can and are changing the way many problems in learning are coded. In this the example used as a focus for the discussion is what is known as the *scale of things*, stuff, from molecules to planets. The presence of these artifacts has important implications for what young children will experience in their everyday life and demand a reconsideration of what is suitable in early years of educational experiences.

Digital interactives sharing molecules and atoms and the Earth as a planet in space are cultural tools of today that can and are being designed with young children in mind. Interactives with scientific ideas of *stuff*, atoms

and molecules, through to planets, stars, and galaxies, from the nanoscale through to the cosmic view, are today readily available, in the everyday world of the twenty-first-century young child. However according to National Curriculum guidelines across the globe, these ideas are not a part of the formal science education until later in schooling. Progress in understanding the power of digital interactives as cognitive tools for young children's development of theoretical concepts, specifically in chemistry and astronomy, across the scale of things, has been explored by a few researchers using positioning theory (Jakab 2013a, b; Jakab and Redman 2017).

Outlined in this entry is support from this research for ICT enabling an earlier *offering of* scientific ideas to young children than was previously considered possible, due to the interactive representations changing the accessibility of concepts for young learners. While this may be so for any concept that a society finds valuable for children to learn, this entry focuses on the early offering of two *big ideas* of science, *the particulate nature of matter* and *the earth as a planet in space*. Current curriculum guideline worldwide recommends delaying the offering of these concepts until middle years or later in schooling (ACARA n.d.) due to the abstract nature of the concepts. This entry explores how an earlier offering can better position young learners for more scientific *ways of seeing and being* in the world, supporting their future positive scientific *habitus* (Burkitt 2002). Evidence for this early offering of concepts through ICT is scant in the literature. A review of the arguments and evidence for providing an earlier groundwork through supporting younger children to *know of* these concepts supports the notion that directing developmental thinking toward the science concepts can minimize many of the alternate conceptions that have long plagued chemistry and astronomy education (Kind 2004; Vosniadou 2008).

Today's games, visualizations, and simulations can provide access to ideas from atoms to planets and galaxies to all age groups. Given that situational factors, such as cultural artifacts, past experience, and cultural norms, limit and direct what children can know and do (Siegal 2008), this

entry raises questions about how the use of ICT visualizations and interactives by young children can more effectively open possibilities of *thinking with* key science concepts.

Exploring Today

Interactives are now available to play and explore any aspect of the world of human knowledge any explorer can think of. An everyday experience watching young children at this tells the observant parent or educator that even the very youngest of today's digitally *connected* children are exploring concepts that until recently would have been thought too complex for them to contemplate, for example, when using a touch phone or tablet to "go" from their home to outer space and back again. Observation of such activity also shows that the child participating in such activity is indeed learning. Today feedback from suitable interactive, not just a human carer or teacher, provides reinforcement of certain activities and constrains others. What works is evident in what happens. Associations are formed. The activity does not confuse. "Real world" and virtual worlds are both experiential and afford certain activities, knowledge, skills, and patterning. Children learn from the activity. In some cases they enjoy and persist if they are intrigued by the possibilities. Through trial and error, a young baby given such a tool will learn to use it. In this entry this activity is likened to what Barbara Rogoff (2003) described, when she observed that a 2-year-old child in a culture where a significant tool is a machete, they can begin to learn to use that cultural tool when positively positioned with it. It is just how the world works. In this sociocultural approach, the tool affords the experience. Experience with the tool builds know-how and then with time becomes incorporated into *habitus*.

Traditional View of What Children Have to Play with

The commonly accepted approach to content in early childhood education is to focus on firsthand

experience in the physical world (Sacks et al. 2011). The emphasis in science learning for young children is playful experience, often contrasted with a focus on information or concept offering (outside that contacted in daily life).

In early childhood science education, observation, classification, and description in this playful experience with physical materials, as compared to conceptual knowledge teaching, have long been emphasized as better supporting early development. The two are put in opposition. Taking a cultural tool view, this approach, that of not offering science conceptual knowledge, privileges traditional everyday concepts, those that are offered in everyday life as commonplace to share with children. But what is missing from this approach is acknowledgment that what is commonplace is not fixed. As culture changes so too do everyday concepts and commonplace knowledge and, importantly here, what can be made clear, concrete, and easily represented.

What Is Play?

As described by Pui-Wah and Stimpson (2004), play is often “treated as ‘free play’ with no learning intentions. It was a reward or a time for the children to relax after their ‘work’” (p. 343). This idea of play is often contrasted with intentional teaching. By taking a more sociocultural approach to the availability of cognitive tools, including ICT tools such as interactives such as Google Earth or molecule building games, the ideas that are shared and available for playing with are culturally determined. These form the funds of knowledge (Hedges et al. 2011) that background the developing interests of children growing up in a society. But these funds of knowledge are not fixed and are culturally dependent. What the educator, parent, or social other focuses on is what any child then has available to “play” with. This acknowledges that what has been culturally shared with the child directs their ways of thinking and being in the world, their future ways of thinking, their *habitus*.

Exposure to fiction and imaginative stories is accepted as vital for young children’s growth

(Scott 1998; Vygotsky 2004). The ability to represent is enhanced by imaginative play, in which one object is made to represent another. Use of culturally accepted ways of doing and saying are rehearsed in such interactive play experiences.

There is ample support for the notion that what is accepted as developmentally appropriate practices, in early years and early schooling, underestimates what children today can do and know (Siegal 2008). What a young child can achieve, do, and know is now acknowledged as dependent on their positioning with ideas and practices (Howie 1999): what a child (or indeed any learner) can do or know in a situation is dependent on how they are situated and positioned in the situation. The material and social resources at hand at the time and their rights and duties in the situation direct development. This conceptualization of learning emphasizes that a learner’s engagement and achievements are not only dependent on their personal history and internal cognitive states (prepositioning); the thinking tools made available for exploration will change what is possible (Rogoff 2003) and the trajectories that will be enacted. The changing teachability and learnability of concepts due to ICT is a current major area of research, mostly at secondary and tertiary levels. What was once unlearnable using previously available thinking tools can now be far more learnable (Noss 2012). This is so for all people – scientists and young children – alike dependent on what resources they have at hand.

Playing with Science

Young children enjoy *playing* with science. The science they are encouraged to enjoy today in early childhood and early school years is reasonably described as hands-on exploration, with *concrete* materials rather than *abstract* ideas. The offering of abstractions in teaching, big ideas, or major theories is routinely held back until secondary level of schooling due to what might be labelled *fears of misconceptions*, which have also been associated with a lack of interest in science in later years (Alexander et al. 2012). Currently what science is for young

children is based around processes of observing and describing, with conceptual knowledge offering being limited to that in their everyday world.

This approach has been in place in curriculum guidelines for over 50 years. While today there is arguably more emphasis on science in early years curriculum than previous times, the nature of that science is still very much the same, focused on sensory exploration and description of events in the world of our senses. At the same time, an ever-increasing public disengagement with science is well documented (Archer et al. 2012).

Digital Interactives as Everyday Artifacts

Along with changing daily life, digital technologies present many challenges to education across all levels in the twenty-first-century. A flurry of education research has ensued, as is evidenced in the broad range of explorations offered in this encyclopedia. This entry explores a lesser researched aspect of the challenges being faced (Smetana and Bell 2012), the changing nature to what is “intuitive” for young children today, through the experiences afforded (Gibson 1979) by digital tools, for those growing up in twenty-first-century computer-assisted societies. A small number of researchers taking a sociocultural perspective on development and learning are highlighting the need to reconsider the age-/stage-derived idea that concepts can be considered *abstract in and of themselves*, by acknowledging that learning is performative (Arievitch 2007; Saljö 2010).

Digital interactives are now commonplace everyday *cultural artifacts* (Lidar et al. 2009) available to even the youngest members of ICT-rich societies. As anyone who has watched a 3- or 4-year-old child *play* with Google Earth will know, zooming in and out – from the local area to off Earth – can be fun and of interest and offer the child both physical experience with using the technology and ideas about the Earth as a planet in space. When suitable social support is provided to encourage such thinking, what is possible for

a young child in terms of their conceptual development?

There is a very easy way to observe firsthand that *what is intuitive* for a child (or adult) is culturally dependent, as compared to there being some base set of unchanging phenomenological primitives that underpin experience. Offer a screen to a twenty-first-century very young child. What interaction with this tool would you expect from a 1-, 2-, 3- or 4-year-olds? The likely response is a tap or swipe with a finger across the screen. The child has set out on a trial-and-error exploration of what happens when the screen is tapped in different places. Causal links are made.

Exploring Early Development with Digital Tools

One change that has occurred in schools that is working its way into the curriculum due to the changing times is teaching coding to very young children, which effectively establishes a grounding for future coding work (for those going on in the field) and a more ICT literate general public in the future (for those who do not). Another change is use of touch screens and personal devices for better communication in both mainstream schooling and for a range of students with special needs. Many changes to conceptual learning in science education with the use of digital tools is occurring; however the majority of the research is being conducted at secondary and higher levels (Smetana and Bell 2012). The proposition that twenty-first-century digital interactives can be effective tools in supporting and redirecting younger children’s conceptual developmental trajectories has had less attention in the literature to date.

Matter and Space: Abstract Concept or Conceptual Tools

Prior to the digital revolution, extensive research programs have been conducted over decades, documenting the problems school children have

with science learning, particularly the nature of the *stuff* of the universe. Summaries of the research into learning issues in the topics of interest here are available: for the concept of particulate nature of matter (Kind 2004; Skamp 2011) and astronomical thinking, in both conceptual change (Vosniadou 2008) and sociocultural approaches (Ehrlén 2008; Jakab and Redman 2017). The proposition that digital interactives can be used to help make concepts routinely labelled *abstract*, such as particles and planets, more accessible earlier in education, is an important though somewhat neglected topic ripe for exploration in this digital tool era. At this time, the idea that digital interactives are changing the learnability (Noss 2012) of concepts for young children is beginning to gain some momentum.

There is mounting evidence that young children are getting greater exposure to some concepts in everyday life than is supported in early years education. That such *funds of knowledge* can support a more scientific *habitus* (Sikdar and Fler 2015) is less well established. Could conceptual development be better supported by acknowledging that children can know and do far more than previously considered possible due to the educational opportunity that current technologies hold for visualizing and supporting exploration of concepts?

History of Representing the Scale of Things

Long before such digital interactives were extant, over 60 years ago, in 1957, a groundbreaking book by Kees Boeke was published – *Cosmic View: The Universe in 40 Jumps*. This little book offered the *scale of things*, from the human to that of the universe, in a combination of representations available at that time, in illustrations and words, to make concrete for adult learners “40 jumps” in scale. That book was made into a 9-minute color movie by Charles and Ray Eames, in 1977, using the best imaging tools available at that time. The film made *thinking with* the scale of

things far more accessible for the viewer at that time. While not an everyday concept for the wider public, the idea was thus supported in entering common knowledge.

The cosmic view is powerful and important to conceptualize for scientifically literate in twenty-first-century society. Using the scale of things helps a person to orient himself when thinking about the nano-world of atoms and molecules, cellular level of DNA, viruses, and microbes, through to the distances across the Earth’s surface and the vastness of space. Today’s digital interactive tools, such as Google Earth, are ubiquitous, so that zooming in and out has become a popular game-thing for even the youngest of the “connected” generation to play with.

In 1998 the importance of the *Powers of Ten* film was acknowledged as culturally, historically, or aesthetically significant, awarding it a place in the United States National Film Registry. Today, this short film and other versions demonstrating the same embedded concepts are readily available online for anyone to peruse for themselves on personal digital devices, anytime, anywhere. These interactive representations bring to our screens the possibility of *knowing of*, playing, and working with *the cosmic view*.

The Scale of Things Today

Today an online search of the term *The Scale of Things* will produce a huge array of hyperlinks for the searcher to choose from, each of which can lead to a further wealth of resources to explore, helping to visualize complex concepts, making them more concrete. The scale of things can still be difficult to grasp fully and use accurately, for experts as well as novices.

The digital tools being developed for everyday use such as Google Earth can help with the meaning-making about the *scale of things in the world*. They are useful conceptual tools for everyone, scientists and children. Making use of such tools can provide meaning-making experience on which a more scientific *habitus* can be grounded.

As described by Leontiev “The human tool is not just an object with certain physical properties. It is a sociocultural object, an object in which historically developed operations are embedded” (quoted by Arieievitch 2007).

Children and Digital Tools

In exploring the literature in this area of the interactions of young children with abstract science concept development, a tacit assumption is found in many articles: that science (abstract theoretical) conceptual knowledge is best developed at secondary school level. For example, a recent review of computer simulation use in science learning literature, Rutten et al. (2012) proclaim: “We focused on students from 12 to 20 years old, as these are the most important years for the acquisition of basic scientific knowledge” (p. 137). This sentiment is widespread and supported in National Curriculum statements across the globe.

Concurrently science is ever more important in daily life, and ICT is affording ever-increasing opportunities for exposure to abstract concepts, scientific, and otherwise, from a young age. The long road to fully understanding any concept however begins with first steps, what is described by Jakab (2013a) as a first *knowing of*.

Early Learning About Matter

Currently the dominant mode of opening scientific discussions of what is matter with young children in curriculum designs is to start first with macro-world sensory phenomenal description of physical materials and then consider physical change and chemical changes as observed with our senses. This descriptive work in science learning is currently being carried out by young children with the support of adults in their everyday and school learning to help them construct meaning, without reference to atoms and molecules, the dominant scientific basis of chemistry, what might be described as the particles toolkit.

The study of children’s (pre-)conceptions of matter, substances, solids, liquids, and gases based on a set of everyday uses of these words is

extensive (Skamp 2011). But what can happen to this learning trajectory when more scientifically sophisticated ideas are shared earlier? What intuitive notions or everyday preconceptions are displayed today?

By offering young children the very idea that matter (in normal conditions on Earth) is particulate, many of the alternate conceptions described in the literature as prevalent can be avoided. Specifically the idea that matter is continuous does not need to underpin everyday experience, as providing particle concepts earlier can eliminate this alternate conception.

Decades ago, Novak explored the use of multimedia to offer young children the concept of the particulate nature of matter. The conceptualizing tools available when Novak designed his intervention included use of taped lessons and recorded images. The results of a 12-year longitudinal study of the science concept learning when early years students were given one intervention about particles showed a lasting benefit of the intervention, with students doing better in late secondary school chemistry than their counterparts (Novak 2005). Despite this research showing clearly positive results, there has been no concomitant change in curricula designs in chemistry for young children. The documentation of children’s alternative to the scientific concepts, so-called misconceptions, continues. Particle ideas are often named more of a problem than a solution to children’s chemistry learning (Skamp 2011). These problems evidenced in the literature for decades show little sign of being reversed with current practices. As Kind expressed the problem remains. How can chemistry learners be better supported to *see with molecular spectacles*.

Cultural Support for Molecules

Today’s visualizing tools are far more sophisticated and interactive. One of the well-designed site freely available for any young child to play with is at the Molecularium (The Molecularium project 2004). The Build game at this site focuses on the proposition that molecules are built with atoms. Children playing this game have been shown to raise scientifically sophisticated

questions about particles of matter (Jakab 2013a, b). The research highlights that when offered the opportunity to know of particles, young children express knowledge of molecules and atoms from everyday life – from television, newspapers, museums, and stories. They raise scientifically appropriate questions about the concepts and, importantly, show interest in learning the concepts through sustained interest in questions raised. The pathway to expert use from the early novice starting point of such particle representations in explaining “stuff” is a long road that necessarily starts with the tottering first steps of the novice (Jakab 2013a, b).

What the children did with the offered knowledge was intertwined with two factors: firstly, what the interactive supported them in doing and, secondly, the social feedback given for their actions. Positive positioning by the more expert social other in this research extended their questioning and helped support their beginning interests in more scientifically profitable directions. This positive positioning of the child with chemistry concepts as they explored with the digital interactive provided experience with the words, images, and relationships important in science about the particulate world. The very existence of molecules and atoms was new knowledge for some of the young research participants, though the majority of the 6–12-year-old study participants had some everyday knowledge of atoms and molecules from daily experience in life – television, books, stories, and news items. The offering of the words and the progress through the interactive positively positioned them with particles ideas as new tools to use in their thinking. The particle level and the symbols in chemistry are combined in the Molecularium Build game, along with information about the physical substances.

This first *knowing of* the concepts using the interactive opens the door to more sophisticated scientific thinking. It provides the groundwork that allows progress toward further knowledge and use of that knowledge. The children were able to make use of the concept for their thinking in scientifically profitable directions, and, importantly, interest was created for the young learners,

for example, wondering what a molecule could be. The knowledge being shared can go far beyond what young children in the past could have had access to, in a large part, due to the ready availability ICT, and in high-quality filming of the natural world. Today’s science factual storytelling is being supported by visualizations, animations, and interactive games that young children can readily use for their own purposes.

Such first steps might be described as *performance before competence*, which is highlighted in cultural approaches to understandings of human development, as a valid stage in learning (Rogoff 2003; Cazden 1997). Sociocultural theory directs attention to the central role of interaction with more expert others in supporting higher mental functions. Only after this mediation through supported interaction or scaffolding by a more expert other will the activity become independently performed by the individual, using their own mental resources (Vygotsky 1987; Wertsch 1997).

The research by Jakab and Redman (Jakab 2013a, b; Jakab and Redman 2017) addresses the challenges presented to education with the changing cultural landscape presented by digital technologies. Their research explores what children growing up with these tools available are afforded, when the child research participants were positioned with suitable digital interactives to offer the possibility of enabling earlier conceptual learning (The Molecularium project 2004). The *building* of molecules from atoms of carbon, hydrogen, and oxygen offered in the *Nanolab Build* game offered opportunity to explore the central proposition of chemistry: *molecules are built of atoms*. The children showed interest and curiosity about the concepts achieved in the trial-and-error efforts and asked scientifically sophisticated questions. Importantly the children in this small study, aged 6–11 years old, thought that these ideas should be offered to children “before 8 years old.”

How did these digital cultural tools change possibilities for learner’s conceptual development? They provide thinking tools to change what might be intuitive or phenomenologically effective to do and think in the situation. In

contrast to most works exploring challenges posed by technology to education, this research probes the changing possibilities of learning concepts in early childhood and early school years in the *zone of proximal development*. In contrast to the majority of research conducted so far in changes to learning of conceptual knowledge, the research discussed here afforded by technology focus on secondary and tertiary student levels when using computer-aided simulations, as summarized in 2012 by Smetana and Bell (p. 1343) in sciences. While the entry focuses on early learning, many of the points raised could also inform researcher thinking about the changing nature of concept teaching possibilities for all ages. The research and approaches described here extend on the idea of *pedagogical link-making as defined* by Scott, Mortimer, and Ametller (2011). Taking a neo-Vygotskian view, this is the external presenting the extent of expert understanding of the proposition that an initial step in learning concepts can be described as a first “knowing of” a concept and can be better offered through well-designed ICT. This positioning young children with a concept using ICT, with its rich combinations of words, images, animations, and symbols and interactive facilities, is not just changing the teachability and learnability of concepts for older students and adults, but redefining what might be considered developmentally appropriate for younger children.

Learning About Earth with Visualization Tools

Privileging one tool above another necessarily shapes the ways individuals can represent phenomena and come to solve posed tasks. When thinking about ideas of the Earth, what tools are we putting in the hands of young children?

Conceptual change research (CCR) has documented many problems students have with the scientific concept of the Earth using clinical style interviews as research tools (Vosniadou 2008). These interviews require the child to

provide answers using their own resources. If however very young children are provided with an Earth globe as a material resource when interviewed about their understandings, taking a more sociocultural approach to what comes out of interviews, many of the problems documented in what the children say do not appear. Schoultz et al. (2001) conducted their research interviews with a small Earth model in the room, so the child was positioned with the tool to aid and direct their thinking. Indeed today, with the everyday presence and easy access to Google Earth and satellite imaging, the problem for the child is changed. Even the youngest members of our society are exposed to numerous images of the Earth as a planet in space in daily life and can “play” with changing scales of images, getting immediate feedback to their actions.

A swiping action with a finger to zoom in and out magnification when looking at images of the surface of the Earth (on a screen) might have seemed strange in the recent past, though testing physical objects by banging, biting, dropping, scratching, and cuddling has always been what babies and young children do to find out what happens, what works through interacting with the world. By constant trials children learn the differences between appearance and reality and not confused by such differences (see “Kids, Appearance, and Reality” in Siegal for an excellent summary of this work). What will occur when any object is offered to a child depends on their past experience with that offered object. By testing the uses that an object can be put to, its affordances, the child explorer develops understanding of how their world works. Testing the affordances of any physical object established a multiplicity of uses and possibilities.

In learning to speak, the affordances of a word are made through affordances of the utterance of the sound. The affordances of an action discovered in the doing. The world the child finds themselves in, of objects, words, images, and actions, is explored through what they afford, “what works, how, and when.” The digital world is another world to explore, a virtual reality, another world that offers different experiences from those

in the physical world, but relate to it, and can be explored to provide experience that can be interlinked with physical action and mental activity.

Swiping with a finger across a screen to activate a phone or touch pad, for example, is today a culturally appropriate action that is reinforced as it affords certain outcomes, based on situated experience with ICT tools. Such action is not a universal intuitive preconception. It is *know-how* with digital tools, as any other tool, built through experimentation in a virtual world, the same as it is in physical world. The expectation that a finger swipe action will produce a result on a screen is based on experience. The act of a finger swiping across an offered screen directs the carer's attention to the fact that the child has been afforded a response to such action with such devices in the past. Indeed, today many of us will acknowledge we have found ourselves making that "intuitive" swiping action on non-interactive screens, such as non-touch computer screens, mechanical cooktop controls, and even analogue watches.

Today digital interactives are a set of cultural tools that are constantly being refined and upgraded and ever more accessible and available for even the youngest human to interact with and experience as part of their everyday world.

Making use of Google Earth to explore the Earth affords the young learner with a big current cultural assumption that "the Earth is a planet in space." This is a hinge concept, providing a basis, acting as the ground on which Earth and space ideas can be explored scientifically. If it is provided as a certainty, from earliest years, with images of our planet, one of the great icons of our time, the child moves forward from that accepted known. With a first knowing of from a young age, the concept can be explored, questioned, understood, and used as a starting point for our being in the world.

Positives of Taking a Sociocultural Perspective on Learning

The great value of taking a more sociocultural approach to the conceptualization of the issue

under discussion here lies in appreciating that what is developmentally possible is not fixed, but rather what is developmentally appropriate is culturally and historically dependent. As described by Rogoff (2003): "This perspective has shifted our understanding of cognition from a focus solely on the thoughts of supposedly solitary individuals to a focus on the active processes of individuals, whether momentarily solo or in ensembles, as they engage in shared endeavours in cultural communities. [] Cognitive development is an aspect of the transformation of people's participation in sociocultural activities" (p. 237).

The differences between the individualistic constructivist conceptual change and sociocultural approaches to conceptual development have been contrasted by a number of researchers. Taking a pragmatists view of meaning-making (Lidar et al. 2009) provides opportunity to explore the challenges that changing culture can make to learning progressions.

In exploring the literature in this area of the interactions of young children with abstract science concept development, a tacit assumption is found in many articles: that science (abstract theoretical) conceptual knowledge is best developed at secondary school level. For example, in a review of computer simulation use in science learning literature, Rutten and van Joolingen et al. (2012) state: "[W]e focused on students from 12 to 20 years old, as these are the most important years for the acquisition of basic scientific knowledge" (p. 137). This sentiment is widespread and supported in many National Curriculum statements.

An alternate view is that not offering concepts may encourage developmental thinking in less desirable directions, toward everyday or folk ideas and away from the more scientific. Development of a positive science *habitus* is more likely when there is an exposure to processes and key concepts of science as tools for thinking. Constraining thinking toward the science concepts is a productive use of science teaching time. In exploring early use of molecule concepts, for example, an initial "knowing of" the ideas

provides a basis for ongoing refinement of the learners “knowing how,” and “knowing that” with these ideas (tool-use combination) is seen as a process of change in thinking over time (Jakab 2013a, b).

Culture aids development in three main ways, through the social supports that are given, participation in everyday activities, and in the cultural tools or artifacts that are available (Gauvain et al. 2011; Stahl 2012). Thus rather than a universal or fixed developmental progression from intuitive preconceptions or phenomenological primitives, what is *intuitive* is dependent on experience, as outlined in the ecological approach concept of affordances (Gibson 1979). Taking a more pragmatic view of development allows for cultural everyday experience, material tool availability, and support of others in sharing accepted ways of being and doing, to lead and direct development. Adding culture to study of development in tentry-first-century child allows for the changing possibilities according to the availability of digital interactive artifacts.

Sociocultural researchers are thus asking: What is *intuitive* for a digital world child today? What is now possible by doing and achieving with digital tools? Just as any other tool, a book, a fork, numbers, doors, etc., what a tool affords depends on its availability for use of the learner along with the social supports the learner has when using it. With time, increasing knowledge about and how to use the tool, that tool can become part of the person’s toolbox, what they habitually use or bring to hand when needed (Gauvain et al. 2011).

Conclusions

There is considerable research showing that digital visualization and simulation technologies are changing the teachability and learnability (Noss 2012) of ideas previously accepted as highly “abstract” concepts. Many of these so-called “abstractions” are held back to later years of schooling, including the particulate nature of matter and ideas of scale as they are considered too *abstract* and difficult for younger children to work with.

A small body of research supports the notion that positive positioning of young learners with concepts, using currently available ICT visualizations and interactives, does enable or leverage young learner interest toward and taking on a more scientifically sophisticated *habitus*. A limited range of research articles published indicate that the provision of key scientific language, images, animations, and visualizations with ICT tools can support young learners to positively *know of* and engage with concepts – including the particulate nature of matter, gravity, and the Earth as a planet in space. This *knowing of* the concept, as a first step, can subsequently lead to opportunities to know more about and do more with the concept, thus leading to an increase in a positive disposition and engagement with the meaning-making about and with the concepts.

The tentry-first-century everyday cultural tools afforded by the rise of ICT can change the way a child visualizes, presents, and represents many concepts. The very idea of size and distance can move from what they were once (considered), that is, difficult and “too abstract” an idea for most people to imagine, to today being a concrete activity that even the youngest independent human can experience in the virtual world, when provided with suitable support. Young children today are exploring the Earth, molecules, genes, germs, viruses, ocean depths, black holes, the universe, and so on. They are developing everyday knowledge about and importantly can acquire skills with these concepts, using digital devices and a set of virtual thinking tools. Ideas such as “humans live on a small blue dot in the vastness of space” (Redman 2004) down to the structure of DNA molecules, the arrangement of atoms of say in water at different temperatures (Molecularium), and manipulation of subatomic particles to create atoms in a game or in a lab are accessible realities for today’s children, adults, and scientists.

Understanding how ICT tools and digital interactives can and are changing what is in the everyday experience of children will help us better understand what is *intuitive* for children today and how the concepts we want to be built into person’s *habitus* (Burkitt) can better be supported. Offering books to babies was once

considered unnecessary but was shown to rapidly increase literacy rates. Offering reading as a valued tool, allowing experience with the tool in books for babies, reading to babies and toddlers, showing that reading was valued and providing social support for reading, turned reading (and also writing) into everyday activities that a child experienced before they were competent with the tool. Performance before competence is an important step in learning.

In the research cited above, when positively positioned with “the idea,” the ground is prepared, affording a young child the possibility of learning experiences that are in line with, or constrained toward, more scientifically sophisticated “ways of seeing.” In this way, the ground for first knowing of the idea is prepared.

The great power of digital interactives as educational tools is that they can offer complex concepts in suitable combinations of words, images, and symbols in multimedia and interactive formats, providing representations and interactive experiences including instant feedback, which can act as a grounding for a better initial understanding of ideas that in other noninteractive formats – drawings, writings, and even moving images – could be difficult for the novice to manipulate and rehearse accurately. The digital interactive format can better position a person, be they child or adult, to begin the process of “seeing what might be” and providing instant feedback that is differentiated for the specific learner needs and their mastery of specific challenges. Digital interactive tools can embed current understandings and in their use *open the door* to new ways of seeing. They can also inspire the person to move forward in exploring of the interactive, be it a game or other format, with a sense of anticipation.

Implications for Early Childhood Education

We must take a positive stance in facing the contemporary challenges that arise about what is accepted as most suitable in science curriculum, following the tradition of curricular change

suggestions based in both changing theoretical understanding and cultural change. A revisiting of what children can do and know today, when they are positively positioned with digital interactive devices, is called for at this time in history, to explore what children can know and do in this ICT-enabled world.

A plausible way ahead to supporting more scientific conceptual thinking, with science or other concepts, is to provide ICT experiences that allow an early first *knowing of* and exploration when a child shows interest. Asking questions about the conceptual tools is a step to better knowing, even for the youngest children. A fear of misconception development has perhaps got in the way of opportunities to “know of” key scientific ideas earlier in learning progressions.

As the researchers exploring the Molecularium with young children conclude (Jakab and Redman 2017): “chemical educators would do well to acknowledge that current visualisations are changing ‘learn-ability’ and can support more scientifically accurate and more sophisticated chemical thinking at a younger age than occurs in current practices. One of the benefits of an earlier introduction would be a decrease in conceptual load seen in senior secondary chemistry, by giving learners more time to appropriate the ideas and develop more habitual and expert uses of and with all three levels of chemical thinking (p. 11).”

At this point in time, it is vital that National Curriculum guidelines, such as Australia’s (ACARA n.d.), are questioned and revisited, in terms of what key ideas and concepts can and should be offered to young children with the use of ICT tools. Digital interactives can better position children for a first *knowing of* and subsequent taking on of key concepts into their habitus earlier than using previously available tools for thinking. Working with these ideas allows interest in science ideas to lead (as compared to follow) develop. Perhaps many of the disengagement problems and alternate conceptions developments that have been long identified could be averted. A better sharing of the scientific view of the nature of *stuff* in the universe using ICT is possible. The last word is left to a year 10 chemistry

student: “I think kids in kinder should be singing songs about the periodic table. That would help ...that’s what I think. I shouldn’t be struggling to remember it now – it should already be part of what I know” (Jakab 2013a).

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Positive Integration of ICT to Reshape the Learning Process in Large Corporates

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Learning at Workplace

Even after recruiting best people from job-seekers, many organizations need to train people for several reasons: to blend human resource with the policy and procedures of an organization, updating knowledge with current work environment, market change, and changing demand for service. Adaptation to the rapidly changing market with a view to maintain competitive advantage in the industry warrants specific training over time. Increased competition due to globalization is another impetus for frequent updates of operational aspect of an organization, needing upskilling human resource, mostly by training.

Learning in small or medium organizations is not very difficult as frequent face-to-face interaction helps transmission of knowledge. In large organizations like corporate, it is a challenge particularly with workstations widely dispersed and information or technology need to be disseminated within a set time.

Up to the last quarter of nineteenth century, most corporates arranged training for human resources by hiring attractive venues, bringing renowned speakers or successful business figures, and spending fund for incentives. Training rooms were considered top grade if fitted with projectors and other audio-visual devices and assessments were mostly classroom-based.

Updating knowledge of the human resource in a large organization with widely dispersed working areas, diverse work role, and sometimes with only a few people in one specific operational area is a challenge. It might be possible to conduct the induction training at a center but not for ongoing issues. Learning needs in the corporate vary. One study suggests most needs are focused on service (27%), sales (22%), technical (21%), other (20%), and regulation (10%) (Merkel and Cohen 2015). It also mentioned that most learners used the presentations on the topic, in the repository, to improve their learning compared to the lesson plan or software simulation.

Today, digitalization with the support of broadband internet is rapidly changing the mode of training. Development of webpage and access through membership is the turning point of disseminating knowledge among human resource. To improve the quality of human resource in a corporate, the word “training” does not fit rather it should be replaced by the word “learning” and more precisely “continuous learning.” In some organizations, it is “learning and development” (L&D). Most learning is now web-based learning or E-learning (Nicholson 2007). Updating knowledge is an ongoing learning process rather than a specific center-based training. So, this entry will focus on continuous learning in corporate.

Learning Process at Corporate

The objective of the learning is to improve different skill sets like motor skills, verbal or communication skill, intellectual skills, cognitive skill (with challenges to thinking), and positive attitude to the task, as deemed necessary by the organization (Knowles et al. 2012). The focus might be on

two important components of learning: cognitive (that is recall of knowledge and development of intellectual abilities and skills) and affective (that is changes in interest, attitudes, and values and the development of appreciations and adequate adjustments) (Wood et al. 2018; Peleckis 2015; Russo and Benson 2005).

To ensure quality learning, evaluation should be there, which could be goal-based, process- or system-based, and outcome-based evaluation methods (Zinovieff and Rotem 2008). Goal-based evaluation is that to what extent the programs are meeting predetermined goals or objectives. Process-based evaluations identify how the performance improves interaction with stakeholders in delivering the program. Outcome-based evaluation is that how it improves the end result like satisfaction level of the stakeholders.

To maintain effective learning, organizations need to select a system according to the structure of the human resource and their availability to participate in the process. In most cases, corporate has adult workforce, so they would benefit following the principles of adult learning.

Adults have more life-experience than children and adolescents. That is why problem-based learning is more effective for adults, where learners are engaged in resolving the problem and the instructor acting as a facilitator. It is better that the training process recognizes the individual variation in learning and should tailor instruction according to participant's preference (Collins 2004). The adult learner prefers to be actively involved in learning and expecting the instructor acting as a facilitator. Problems in adult learning are prejudice, set habits irresponsive to change or resistive to new things, resistance to direction or command. Adult learners want freedom to choose, timely feedback to correct errors, to continue learning, and gain mastery of content and skills (Knowles et al. 2012). Workplace training with adult learners would therefore succeed if following actions are present: encouragement to create interest to learn or curiosity for the topic to learn, motivation on the reason and the process, justification based on past experience, relationship to current or future situation, autonomy or

self-paced learning, scope of experimenting or testing, and stress-free learning climate.

Self-directed learning with justification for the task is a better option for adult learning (Knowles et al. 2012; Collins 2004). Adult's motivation comes from comparative analysis that is a gain or benefit from current situation. Information on the impact of the learning on the work or to other responsibilities is valued by the adult learner. From that point, it is also beneficial to use the term "learning" rather than "training or coaching," as the adults might feel comfortable to improve their performance by themselves or gaining knowledge and expertise rather than feeling a teacher is directing them to do something in a classroom. The learning program needs to identify the learner's needs in consultation with the learners and learning activities be designed relevant to those needs.

Training program for adults needs to address the general principles like acceptability of content to the participants, goal oriented, relevancy oriented and practical, acknowledging the life experience and knowledge of the participant, scope of active participation, incentive to participate, immediately applicable to real-life contexts, climate of respect and comfort, and positive outcome in applying the learning (Lee et al. 2005).

Learning from an employee perspective needs consideration for any training program. As mentioned in the adult learning principles, learning depends on justification for it or need for it. In an insecure job market, employee will not consider spending much time on learning. Job security and potential for progression to higher position would improve learning. So, willingness of employee to engage in learning will depend on job security. Today, in most cases, employee does not want to learn but want help at the point of need.

In any learning process, it is also important to identify how frequently human resource be engaged in learning. The psychologist Hermann Ebbinghaus's memory retention curve could be a guide for organizations to arrange a schedule for training (Murre and Dros 2015; Custers 2010). The curve shows how quickly people forget after a learning session. After 10 min, 30% memory is

lost, and after 1 week, 90% is gone, in the absence of any refreshing or remembering activity. This brings the need for mobile devices to boost personalized learning process for the learner.

Assistance for talent development's (ATD) 2017 report (Ho 2017) mentioned that organizations' commitment to learning, the average number of formal learning hours used per employee is growing (grew from 33.5 h in 2015 to 34.1 h in 2016). These are stand-alone hours that are not embedded in work activities.

Traditional fixed center-based learning is weaning with the demand of accessing training at any point in the world at personal time preference. Traditional, instructor-led, face-to-face classroom-based training still contributes 49% of learning hours of the corporates, used in 2016. But the technology-based learning (E-learning) is rising (45% in 2016 compared to 41% in 2015). Both learners and instructional designers are upskilling in using technology, and also the user-friendliness, flexibility of the technology is improving. (Ho 2017)

The online learning management system started as an application to automate the administration, tracking, and reporting of training program in support of classroom education. It was intended to provide opportunity for self-service and self-guidance, rapid delivery of learning content at the users' preference, and personalize content with option for repeated access (Subramanian et al. 2014). Today, online learning is moving beyond any limit, not just supporting the classroom activity.

Online learning could be synchronous or asynchronous. Synchronous training is real-time training where trainer and trainee are online at the same time. In asynchronous training, entry (log-on) or exit (log-off) is personal preference both for trainer and trainee as the contents are in particular page and both have access to complete their task at their convenience.

The online training or E-learning system is described by several names, for example, computer-based training (CBT), computer-managed instruction (CMI), distributed online learning (DOL), learning management system (LMS), or learning virtual environment (LVE). Whatever

may it be called, these tools have three main user profiles: system administrators, teachers, and students (Guenaga et al. 2004).

E-learning provide an alternative way of learning comparing to traditional classroom learning for people with disability (Debevc et al. 2007). Web-based training (WBT) has helped removing the barrier of distance and making the presentation lively by high-dimension images and opportunity to magnify the image to allow the trainee a closer view of the object. Additional features can make the presentation more entertaining than even the face-to-face classroom experience. It has the opportunity to bring multiple examples in one presentation without even leaving the session. It has the scope to present a topic lively, but it would not be effective if the content and intent are obscured and instructional effectiveness is sacrificed (Lee et al. 2005).

Corporates develop a learning management system (LMS) or learning content management system (LCMS), depending on its structure, its operation, characteristics of the business, human resource, and competition in the industry locally or globally (Iglesias et al. 2014). The WBT encourages corporate to build their own storage system for resources and provide access to its members through certain medium. This is called internal repository that holds different learning content, presentations, or messages.

There are different tools for LMS in WBT program: WebCT, Blackboard, Macromedia e-Learning Suite or Docent Enterprise Suite, Moodle, ATutor, and Sakai. The last three (Moodle, ATutor, and Sakai) are open-source LCMSs (Iglesias et al. 2014).

Blackboard is well known across higher education sector and is a ready to use software. It charges per student or user rate. Moodle a free open source LMS is also appreciated in this sector but is not ready to use software, organizations need to customize it. Whether an organization will use the free LCMS (like Moodle) or paid system (like Blackboard) will depend on factors other than price, that includes: user number (some LCMS can handle more than 500 users', others cannot), ability to integrate with other platforms like Google apps, and smooth running of the

pages without being hanged. They have different functionality: one allows instructors to post course materials, readings, and assignments and allows basic discussion and the other one helps educators to manage the course by creating effective online learning communities to support self-learning (Subramanian et al. 2014). Products like “Internet of Things (IOT)” or “Internet of Everything (IoE)” are also integrating with the system (Dinc et al. 2019).

Supply of the Learning Material

Alternative to main frame computers started to emerge with the commercialization of personal computer in 1977, Apple II in 1978 and associated software (Myers 1998). Gradually, the appearance of discs, USBs, windows, and other mediums helped the expansion of the knowledge sharing beyond the classroom and initiated flexibility to learning. Corporates spend a lot to develop video, animation, and different means to help learning and to assess the participants. This opened the opportunity for WBT.

Availability of web-based training (WBT) is well embraced by corporates. WBT needed a browser, particular language (like HTML) to develop the content, and special program (like Flash) to display video or animation. It needed substantial fund to develop big voluminous content to complete a course. Learners needed fund to source computer with higher speed or storage capacity, subscription to the Internet and LMS.

Still then the level of satisfaction was limited, in value for money. Learners were not able to access it as and when needed. Technological glitch caused problem in accessing the content, hang-up in the middle of its run. It was difficult to get the desired content like searching a tiny fish in the ocean, not user friendly in finding the desired material, and needed the skill of using special jargon or technique. In the last two decades, with the expansion of broadband internet and fast-paced mobile communication devices in the developed countries, the E-learning speeded up.

Explosion of learning material started with the development of open educational resources

(OER) with UNESCO committee as the driving force (UNESCO 2002). The objective of that UNESCO initiative was to encourage open and free resources for all to use for teaching, learning, and research. Providers emerged with different types of repositories for OER (Merkel and Cohen 2015). Simple OER repositories (like Google or YouTube or Wikipedia or Face book) helps getting information that are easily uploaded by any registered provider no matter how much skilled they are on the topic. It serves mostly raw data, unverified and helpful for general knowledge on any issue. It is generated mostly by individuals, low cost production, easy to share by any citizen, provided governments do not interfere. It is good for sharing knowledge but not been well embraced by organization for educational purpose. Some OER repository are institutional repository for teaching with quality for authentication, accreditation, and acceptability in scientific community.

Current successful OER providers brought some added features to attract the learners. Service providers (like Google) improved its search engine with benefit to both general learners to institutional learners. Some OER (like Google, Wikipedia) are holding more than millions of articles in almost all languages of the world (Mesgari et al. 2015). But still matching the learners need is not easy. It is possible to narrow down the search by advanced users but not satisfactory at all time.

Emergence of mobile platform (like iPhone and Android phones) have advanced to bring some satisfaction to the learners by relatively easy upload and download facilities for their own video, provided the respective government agencies do not intervene. It is far easier to make an unedited video and upload or download as long as the carrier phone company has the network. This platform gave birth to a different style learning, i.e., learn from what others are doing and willing to share it with others. Instead of a trainer spending time in designing a course module, one worker or executive can send the video of what they can do and how, which others can accept or reject.

Dynamic organizations are using both OER and internal repositories to help learning, but the

conservatives are restrictive to internal repositories. Still use of internal repository is the main (around 90%) (Merkel and Cohen 2015). Instructional designers and training managers decide what resource to use from which repository. The use of OER in the corporate world might have some limitation if they are for-profit organization. Also use of OER (particularly YouTube and Google) is a common practice for all learners to gain a first-hand knowledge or preliminary information about the topic before entering into any internal repository.

The MOOC concept draws the attention of corporates to bring smoother large volume learning material delivery (Dodson et al. 2015). To facilitate on the job training, some corporates are building partnership with MOOC networking organizations and they predict employees will be required learning all the time (Gaskall 2017). They predict that learning and development will be forced to become an extracurricular activity rather than a core part of one's work. The year 2012 was "the year of MOOCs" as renowned universities joined with private companies to offer open and free, online education (Bogdan et al. 2017). But it is not a rosy picture for all learning program. There are failures or huge drop-outs in the MOOC operated free courses (Rivard 2013).

Around 2010, the LMS got support from a new technology to manage the digital content, mostly in integrating and organizing the contents. This brings following advantages: easy searching of content and faster retrieval of content (text or image or video stream). It is supported by artificial intelligence to generate role specific or interest specific or usage history specific content and notify (by text or email) to its members (who has signed in or subscribed).

National and international encouragements, like OER concept from UNESCO and digitalization policy from governments, have increased the supply of information and communication technology (ICT) to identify the need of employee learning. ICT products, like software HR Analytics, attempts to understand the cognitive aspect of human resource and to analyze data in the human resource department after

employment. It helps establishing relationship between human factors and its impact on the organization including performance and turnover rate (Angrave et al. 2016).

Competition ICT environment changes technology at a very fast rate (Xu et al. 2017). This gives advantage to the industry leaders and proactive leaders but makes life difficult for lagers or reactive leaders. It is now possible to source more personalized service to make the learning program more diversified and specific for each learner.

The effectiveness of E-learning technology in education sector would depend on several factors. Most important is the accuracy or authenticity and fulfilling the standard of the education regulatory authority. Accessibility of users is always a factor particularly for the low socioeconomic group, also the willingness of the corporate or governments to share information need consideration.

As with previous technology adoption in learning environment, it is time dependent, aggressiveness of the corporates to use it in the system, encouraging factors to engage learners or employees in the system. The class-based learning and this LMS learning differ in stimulating factor. In class-based learning, teacher or trainer stimulates to learn or the presence of the trainer engages learners in different activities to learn (may be little bit or more). In LMS, learner's maturity or focus on the issue is the important factor to stimulate learning. Usually people learn when a perceived need is present (Beer and Schrader 2016a; Knowles et al. 2012). With the new technology, if learners or organizations do not change their attitude, then it will not be effective.

Challenges in e-Learning at Corporate

Common problem with WBT is that the learning designers consider only the presenting ability of the technology but fail to identify the justification of the content for the learner or organization and also to identify the difficulties related to navigation process for the learners. Any learning program needs to have effective design of learning content, appropriate user interface design, and appropriate evaluation process (Lee et al. 2005).

Corporates spend on training, but in many cases, the return on investment (ROI) does not match with gain, in terms of changes in individual behavior or organizational culture or even financial performance (Beer et al. 2016a). In some cases, change is very short lived, and people revert to old ways of doing things, initial performance spike drops to base. This might relate to conflicting priorities on strategy and values, senior executives' behavior does not reflect the desired change, poor organizational design hinders honest conversation on problems, inadequate time and attention to talents or critical issues, and fear of backlash for criticism or telling facts. Effective remedial measures include: review of the learning process at regular interval, consider alternatives to current learning and development process, analyze the context for relevancy, and fix design and management process (Beer et al. 2016a).

Web accessibility depends not only on accessible content but also on accessible Web browsers and other user agents.

With inclusion of online learning system as an integral part of training in many countries, the trainers would need to be well conversant with Web Content Accessibility Guidelines (WCAG) and WCAG 2.0 AA standards. This WCAG guideline intends to make web contents accessible to people with disabilities, to older individuals with changing abilities due to aging and even to improve usability for users in general. The World Wide Web Consortium develops WCAG standards and measures the accessibility of the websites by those people (Caldwell et al. 2008). Organizations need to assess and monitor the LCMS to guarantee universal accessibility to ensure participation of all learners (Iglesias et al. 2014).

In light with the WCAG guidelines, it is now a challenge for organizations to improve the accessibility option, so that people with disability or with other limitations can participate in the learning process without too much additional work (Guenaga et al. 2004). The WCAG standard encourages course content developers, instructional designers, ICT professionals, and all other entities involved in the E-learning creation and delivery process to consider alternative tools, platforms, methodologies, and services.

Even though there is optimism in using E-learning system, currently available tools have accessibility barriers that make the creation of accessible E-learning environments difficult for learners and organizations (Calvo et al. 2014).

There is difficulty in utilizing the tools due to misconception using it or proper understanding of the system. While including this ICT in the training program, sometimes organization fails to understand that the people are the center of the system (Dinc et al. 2019).

There are challenges like the Internet or online connectivity, security, right hardware and software, etc. The IOT's are today part of infrastructures in many services. An app in the ICT is great as long as its cyber-physical aspect is known to the user or the creator of the system and proper measures taken to ensure security. It is required to have a "smart cyber-physical system" in the Internet of things to avoid harm in hostile environment like cyberwar (Izosimov and Törnngren 2019).

A system could be safely used as long as the password is kept contained within the secure circle and leak to opportunist people could cause harm or loss.

There is a concern that corporates are failing to identify the learner's interest or need (Anton and Shikov 2018). In traditional classroom training, teacher-student interaction allowed the quick identification of the learner's discomfort or weakness in gaining knowledge. In E-learning, absence of that interaction challenges the training organizers with the task to develop proper assessment task to accurately reflect the learner's knowledge gain and ability to reflect in workplace.

To gain from the learning process, corporates need tools to evaluate the appropriateness of the design of the training and identifying the effectiveness of the process to reflect the organizational perspective (Lee et al. 2005).

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Post-It Board

- [Digital Media Boards in Primary Schools, Use of](#)

Postsecondary Learners

- [Safe Frames, Essential Determinant for Educational Technology Implementation in an Indigenous Context](#)

Practice

- [Computing Education, Practices in](#)

Predicting ICT Skills and ICT Use of University Students

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Synonyms

[Experiential learning](#); [ICT anxiety](#); [ICT hardware](#); [ICT skills](#); [ICT software](#); [ICT use](#); [Identity commitment](#); [Internet](#); [Learning experience](#); [Research orientation](#); [Self-efficacy](#); [Social networking sites \(SNS\)](#); [Survey](#); [Technology acceptance model](#); [Unified theory of acceptance and use of technology](#); [University students](#)

Introduction

One need not be an expert in information and communications technology (ICT) to realize the ever-increasing influence on and omnipresence of ICT applications in the society. It is therefore easily assumed that everyone possesses basic ICT skills and can use simple ICT applications. Especially university students, who are considered to be “digital natives” and who have had ample exposure to a variety of ICT applications and training, are often thought to be a homogeneous group with near-perfect basic ICT skills and highly frequent ICT use. This, however, is contradicted by research, and the current paper aims to provide some answers to the question why university students differ in their basic ICT skills and use.

Like in the social sciences at large, different data collection methods are available to study ICT skills and use (Nair and Das 2011). While direct

observation (e.g., Madigan et al. 2007) can yield high-quality data, it is often expensive and not practical for large samples. Survey questionnaires that collect self-reports of behavior are easier to use in large samples, but may not be fully reflective of the actual behavior or interest. While some have used mixed approaches (e.g., Hohlfeld et al. 2013), most research relies on self-reported data (Nair and Das 2011), as does this one.

While looking for predictors of ICT skills and use, some researchers kept it simple and limited the observation to variables that have quite often shown differences in social behavior, for instance, gender, age, education level, and status (Hargittai 2010; Salajan et al. 2010; Goldhammer et al. 2016; Mansur and Cakmak 2016).

Although these variables can be very useful to detect differences in the society, they leave a lot to be explained. Different theories are available to explain proficiency in ICT skills and frequency of ICT use. The *Technology Acceptance Model* (TAM) has been particularly influential. It was proposed by Davis (1989) in the context of the acceptance of computers. Davis constructed two explanatory indices: (1) the perceived usefulness of technology (will the use of this technology enhance my work?) and (2) the perceived ease of use of a technology (will it be easy to apply this technique?). In 2003, Venkatesh published an article in collaboration with Davis and others in which TAM was integrated into what was called the *Unified Theory of Acceptance and Use of Technology* (UTAUT) (Venkatesh et al. 2003). This theory included the two variables proposed by Davis and added social influence and facilitating conditions to the model. Social influence refers to the perception of an actor that an influential other believes that he should choose for the new technology. Facilitating conditions are expressed in the belief of an actor that there is an organizational and technical infrastructure supporting the use of the technology. Besides these four variables, three additional variables were introduced as indirect determinants mediated by perceived ease of use: self-efficacy, anxiety, and attitude. Self-efficacy is defined as the

degree to which an actor believes that he can do a job without the assistance of another actor. Anxiety refers to concerns in using a new technology. Attitude encloses the affective reaction of an actor toward the new technology. Besides this, Venkatesh et al. (2003) contend that also the usual variables such as gender, age, and experience may aid in predicting the use of new technology.

The success and limitations of the TAM have been documented by Marangunić and Granić (2015), for mobile learning by Al-Emran et al. (2018), and for UTAUT by Williams et al. (2015).

In this entry another path is followed. Former studies (for instance, Papanastasiou et al. 2005; McMahon 2009) have shown that at least ICT use might be positively related with achievement in science subjects and improved critical thinking among young students, but have not investigated this link at the level of university education. Accepting that the study of science familiarizes students with the procedures of scientific research, one can hypothesize that students interested in scientific research will also be interested in ICT. In this current research, based on theoretical considerations presented in the next section, it is expected to find an association between the level of ICT skills and use and the degree to which university students are research-oriented. As explained in the “[Methodology](#)” section, on the basis of a questionnaire filled out by bachelor’s students, the association between ICT use and skills and research orientation, taking into account the ICT learning experiences of the students and some important contextual variables is investigated. Section “[Short Overview of the Main Variables](#)” presents a short overview of students’ access to PCs and the Internet, their learning experiences, and their attitudes toward scientific research. In sections “[Learning Experience and Identity Commitment as Predictors for ICT Skills](#)”, and “[Learning Experience and Identity Commitment as Predictors for the Frequency of ICT Use](#),” both the learning experience model and the identity commitment model are tested as predictors of, respectively, ICT skills and the

frequency of ICT use. In the final section, some conclusions are drawn.

Theory

The Role of Experiential Learning

Learning is not limited to formal learning organizations such as schools, but takes place in all kinds of situations where people meet each other (Cox 2013). From a very young age, children experience pleasure when they can do what others do. They feel they belong to a group because they can act like the other group members, whether family members or playmates (Dewey 1933: 206, 257). Unmistakably, John Dewey (1933: 258; 1938: 236; Kolb and Kolb 2005) stressed the power of experience in this learning process. He emphasized the advantage of belonging to a group where the objective of learning is highly appreciated (Dewey 1933: 38; 1938: 25), and he underlined the capacity of this to stimulate the motivation to learn more about what people need in order to function in a group. These opinions are shared by other researchers. Jeffrey et al. (2011) refer to several other researchers in stressing the importance of the personal relevance of the learning content for a successful learning process. This also partly explains success in learning ICT. Although in many countries ICT is formally taught in schools, an important part of ICT knowledge is gained at home or among friends. In Western societies, ICT is widespread and computers and the Internet have a place in many families. Parents and siblings play an important role in making this technology accepted (Vekiri 2010; Zhao et al. 2010). Children discover how much fun it is to play games on the computer and, more importantly, feel that learning how to work with ICT instruments is also highly appreciated by parents and siblings.

Vekiri and Chronaki (2008; Vekiri 2010) mention research where the link between the socioeconomic position of the parents of the students and ICT use is supported in elementary schools and in secondary and higher education. However, using regression analysis, they

concluded that home computer access, frequency of use, variety of activity, and perceived parental and peer support were not or were just marginally related to students' self-efficacy and value beliefs. Similar critical observations were made by Verhoeven et al. (2010) and De Wit et al. (2012). In a regression model where in addition to social background (the socioeconomic position and education level of the parents of the students), the variables of usefulness and control of the computer, computer anxiety, and Internet competences were included in explaining the frequency of use of computers for study, chatting, and games by secondary school students, no substantial relationship was found with social background. The only relationship found was a lower frequency of computer use for recreation by working-class students compared with other students. The same phenomenon was observed by these authors among university freshmen. The socioeconomic position of the students in combination with other variables showed a minor influence on the ICT skills and the frequency of ICT use of university freshmen. This indicates that influences experienced at a very young age do not always have apparent consequences in secondary school and at university. Moreover, De Wit et al. (2012) also found that the effect of influence might change over the years. For example, they found that in 2005, students whose father or mother had completed higher education were less capable of installing a computer than other students were, but that this relationship was the opposite in 2009. In addition, in 2005 students whose father had completed higher education chatted more online than other students, and those whose mother had completed higher education chatted less. In 2009 both relationships were reversed. In other words, situational developments might change previous relationships.

Peers also play a role in learning about ICT and the Internet. Students mention friends as the second most important source of ICT knowledge (mean score = 3.29 on a scale of 1 to 5) (Verhoeven et al. 2010). Nevertheless, students overwhelmingly consider themselves as the most important instructors of ICT for themselves (mean

score = 4.02), thereby offering a good example of what J. Dewey would call agents, not simple receptors (Dewey 1917; Evans 2000).

This leads to the hypothesis that students whose families, peers, and teachers more intensely support contact with and instruction about ICT will possess more developed ICT skills and will use ICT more often than students who did not grow up in such an ICT-oriented environment. Nevertheless, based on relevant literature, this relationship is not expected to be very strong.

The Role of Students' Identity Commitment

Earlier research has indicated that the vocational orientation of university students significantly influences the use of ICT and the command of ICT skills (Verhoeven et al. 2010; De Wit et al. 2012). Vocational orientation could be called a form of commitment, as defined by Burke and Reitzes (1991) in the following way: "(it) refers to the sum of the forces, pressures, or drives that influence people to maintain congruity between their identity setting and the input of reflected appraisals from the social setting." The identity setting of a university student is, among other things, composed of a belief in his or her academic competence, a vocational orientation (studying for a particular profession), and an orientation toward becoming a scientific researcher or another professional. Interactions with others may support or blur this identity and can influence a student to pursue or abandon these intentions. If the identity commitment is strong, a student will adhere to the expectations of the group that link him or her to a particular identity setting. A student who benefits significantly from living close to this student setting will very probably be more committed to that identity than other students. Burke and Reitzes (1991) discerned two bases of commitment. First, cognitive bases refer to positive rewards coming from interacting with people as a result of maintaining the expected identity. Assuming that a student has an elementary knowledge of ICT, stimulating the appraisal of other students might motivate a student to work harder toward mastering ICT skills. Second, socio-emotional bases refer to ties between people who share

the same position and experience the recognition of others as supportive confirmation of the adequacy of their behavior. When a student experiences the acceptance of other students, he or she will most likely try to maintain interactions with these positive, rewarding colleagues.

A stronger commitment to a professional career in research or in another area, and a belief that ICT will be a necessary or inevitable component of a future career, might lead students to have a stronger commitment to using ICT and using it more frequently. Moreover, using ICT involves taking a number of steps that are also part of carrying out scientific research. This similarity might add (albeit not at a conscious level) to a stronger link between training in scientific research as a part of an identity setting and knowledge of ICT skills and the use of ICT.

Scientific research has characteristics similar to that of an information system, which Zwass (2019) defined as "an integrated set of components for collecting, storing, and processing data and for delivering information, knowledge, and digital products." Scientific research starts with the question of why a particular phenomenon is what it is or why it functions in the way that it does. Researchers start with some hypothetical explanations and collect data to test whether a hypothesis can be rejected or not. Observations, methodologies, and interpretations are stored, because there should always be an opportunity to check and recheck the research data and results. It is also important to have an instrument to rapidly retrieve any data that researchers might be interested in. The process of scientific research does not stop there. Results should be made available to colleagues and a wider audience; they should be publically displayed. Research is also expected to be useful. This all takes place in collaboration and in discussion with the wider scientific community. Researchers collaborate locally but also internationally. Datasets are transmitted from one continent to another, discussed by researchers who live far away from each other, but jointly publish in journals that are read throughout the world. They meet at international seminars and conferences, teach each other's

students, engage in common projects, etc. In other words, scientific research shares many characteristics of information systems as described by O'Brien and Marakas (2009: 4): "An information system can be any organized combination of people, hardware, software, communications networks, data resources, and policies and procedures that stores, retrieves, transforms, and disseminates information in an organization." Each information system comprises some basic activities. In order to obtain information that has to be processed, a worker needs instruments to capture this information (for instance, a keyboard or a scanner). This captured information has to be transmitted or processed to another device (for instance, another PC in a network) in order to work with it later. Therefore, it must be stored (for instance, on a hard disk or a USB stick). When needed in a later process, this information needs to be retrieved. This procedure takes the results of the storage process and uses them to elaborate the information. The old information (output information products) is used to create new information, to reorganize the information, and to recalculate what has been retrieved or for similar operations. At the end of this process, the results are shown to an observer who might be interested in the results of analyzing the information. At the end of the input, processing, output, and storage, a control of the system performance should be established.

This brings us to the hypothesis that students who are interested in scientific research and/or want to become researchers will be more open to mastering ICT skills and/or will make greater use of computers and the Internet for their studies than other students will. Indeed, ICT offers them useful instruments for attaining the targets that researchers have in mind and helps them to be rewarded for showing a commitment to their identity setting.

Methodology

Data for this project were gathered through an online questionnaire filled out by bachelor's students at the University of Leuven (KU Leuven),

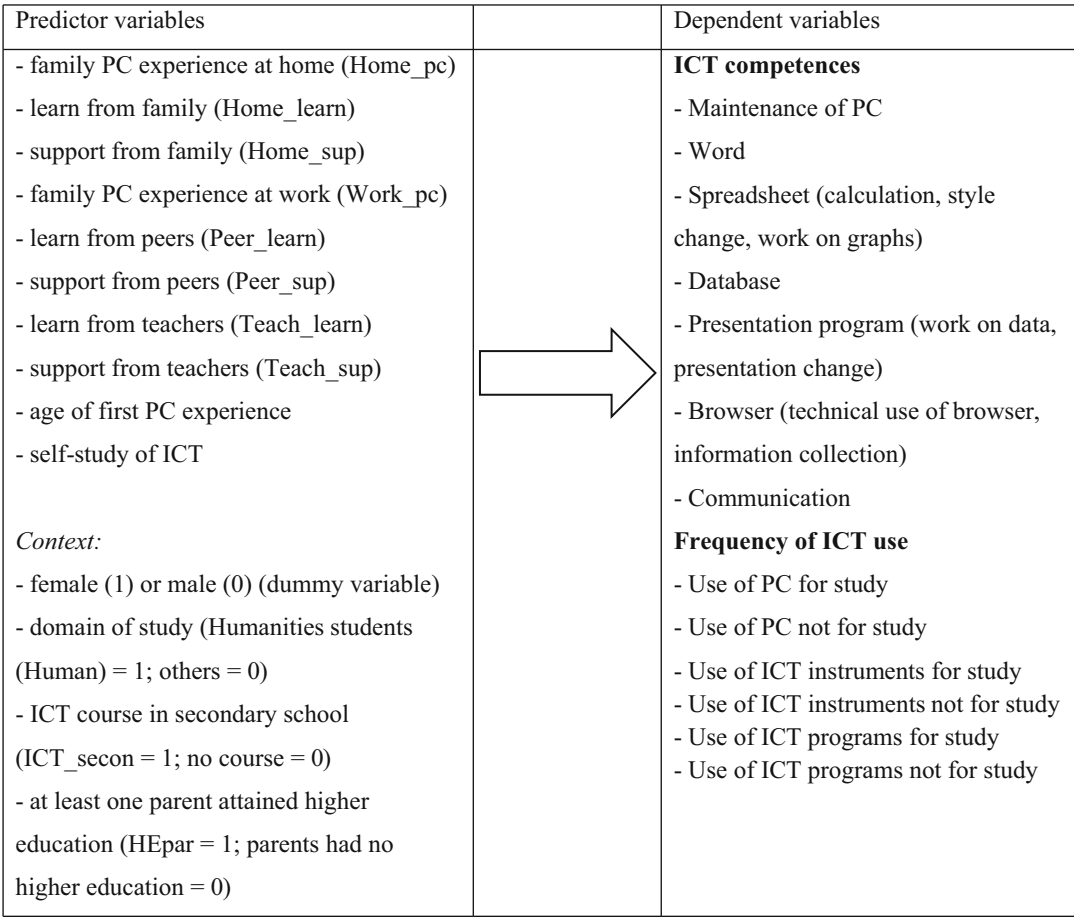
which is one of the largest Belgian universities. It is a comprehensive university with a wide range of scientific disciplines and domains of study. Although the university buildings are spread across the town, the university has a well-developed intranet system offering broadband Internet access to all students, even those in privately rented accommodation. In 2012, the university was attended by 40,257 students, among whom 45% were studying at bachelor's level and 31% at master's level and 11% were PhD students. In this project, research is focused on bachelor's students who had passed their first-year exams and would not take their final bachelor's exam in 2013. This is a population comprising 3,609 students. Most of them had been at the university for at least a year and were supposed to be familiar with the ICT equipment of the university and the expectations of the staff concerning ICT use in and outside classes. In total, 1,232 students answered an online questionnaire between 13 November 2012 and 18 December 2012. Students received up to two e-mail reminders after an initial e-mail invitation to participate in the survey. The analysis used here involves 1,180 students who responded to at least 75% of the questions and fell within the age range of up to 25. Because the multivariate sample distribution for gender, age, and faculty deviated to some extent from the population distribution, a weighting factor was calculated by iterative proportional fitting.

These hypotheses are tested using two models (see Figs. 1 and 2). The first model focuses on the learning experience of the students, and the second on their identity commitment. Both models are expected to contribute to the prediction of self-perceived ICT skills and self-reported frequency of ICT use.

Dependent Variables

ICT Competences

The seven ICT competences in Figs. 1 and 2 are measured using scales consisting of several items. These scales have been used in previous research and have been refined over the years to capture new types of ICT use (e.g., inclusion of references



Predicting ICT Skills and ICT Use of University Students, Fig. 1 Explanatory model 1: learning experience (Verhoeven et al. 2016, p. 78)

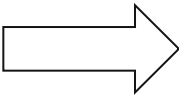
P

to social networking sites [SNS]; cf. Verhoeven et al. 2010; De Wit et al. 2012).

Based on a review of several instruments, in particular ECDL Syllabus 5.0 (ECDL 2010), new items were developed. A paper questionnaire containing the existing and new items (a total of 123 items) was tested in a nonrandom sample of 85 university students. The response format for all items was identical (a five-point Likert-type rating scale ranging from “totally not true for me” to “totally true for me” with the midpoint “more or less true for me”).

The resulting data were analyzed using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) in Mplus version 4.0. The EFA was used to identify appropriate items, and the

CFA was conducted primarily to assess goodness of fit. The selection of the final items was based on the results of the factor analyses and an evaluation of the distribution of the individual items (items with strong ceiling or floor effects were deleted). In total, 49 items were included in the final questionnaire. The items were distributed over the seven ICT skill domains as follows: 7 for maintenance of the PC, 6 for word processing, 14 for spreadsheets, 6 for databases, 6 for presentation software, 7 for browsers, and 3 for communication. All items of the scales are published in Heerwegh et al. (2016). The data obtained from the main survey (1,180 students) were subjected to confirmatory factor analysis (CFA) in Mplus version 4.0.

Predictor variables		Dependent variables
- academic self-perception (Acadsc) - vocational or professional orientation (Profor) - attitude toward science (Attit_science) - intention to become a researcher (Intent_sc) - intention to become something other than a researcher (Intent_oth) - Scientific research needs ICT (ICT_science) <i>Context:</i> - female (1) or male (0) (dummy variable) - domain of study (Humanities students (Human) = 1; others = 0) - ICT course in secondary school (ICT_secon = 1; no course = 0) - at least one parent attained higher education (HEpar = 1; parents had no higher education = 0)		ICT competences - Maintenance of PC - Word - Spreadsheet (calculation, style change, work on graphs) - Database - Presentation program (work on data, presentation change) - Browser (technical use of browser, information collection) - Communication Frequency of ICT use - Use of PC for study - Use of PC not for study - Use of ICT instruments for study - Use of ICT instruments not for study - Use of ICT programs for study - Use of ICT programs not for study

Predicting ICT Skills and ICT Use of University Students, Fig. 2 Explanatory model 2: identity commitment (Verhoeven et al. 2016, p. 79)

Frequency of ICT Use

The frequency with which students use a computer, ICT instruments (hardware), and ICT programs (software) was measured separately for study purposes and for all other purposes. Students were asked how frequently they engaged in specific behavior (surfing the Internet, e-mailing, chatting, goal-oriented online searching, downloading movies or music, participating in newsgroups, writing blogs or wikis, and playing games – the last item was not asked when gauging ICT use for study purposes), how often they used ICT hardware (use of a PC or laptop, Internet, mobile, iPad or tablet, iPod, iPhone

or smartphone, digital camera, and e-reader), and how often they used specific software (word processing, spreadsheets, databases, SNS, Twitter, virtual learning environments, drawing software, statistical programs, qualitative data analysis programs, and specialized software). The response options were daily (score = 6), four to five times a week (score = 5), two or three times a week (score = 4), weekly (score = 3), monthly (score = 2), less than once a month (score = 1), and never (score = 0).

An average score was calculated across all items of each of the three variables separately for study and for non-study purposes (use of a

computer, use of ICT instruments, and use of ICT programs), for use in further analyses.

Independent Variables

Learning Experiences

Learning experience of ICT was measured using several indicators. The survey questionnaire included items on whether the student's father, mother, or siblings used a computer at home (Home_pc; score range = 0–3) and at work (Work_pc; score range = 0–3). Both situations might create a positive attitude toward using computers.

Three questions referred to how much students had learned about ICT from family members (father, mother, and siblings), peers, and teachers. The response options were “I did not learn anything from (e.g., my father)”; “I have learned a little, much, very much from (e.g., my father)”; and “not applicable.” All answers about the degree of learning from family members (Home_learn) were averaged to obtain a scale that ranged from 1 (learned nothing) to 4 (learned very much). An identical procedure was followed for learning from peers (Peer_learn) and from teachers (Teach_learn).

Three additional questions collected information about who might be able to provide support while working with ICT. Students were asked how often they could request help if they experienced problems with a computer or the Internet. A distinction was made between support from family (Home_sup), peers (Peer_sup), and teachers (Teach_sup), and the same response options were provided: never, seldom, mostly, always, and not applicable. The average scores were calculated for each source of support, with the scale ranging from 1 (no support at all) to 4 (maximum support).

Dewey's learning theory also points to the relevance of the learning content for a learner. If something is highly relevant for a learner, he or she will stress this by engaging in learning activities. To obtain a measurement of this, the survey asked how much respondents had learned about computers and the Internet by themselves

(score range = 1–4) and their age when they had first started using a computer.

Identity Commitment

Identity commitment is composed of four indicators. First, academic self-perception or academic self-concept (Acadsc) was measured with seven items such as “I rate myself highly in terms of my academic ability as an undergraduate,” “I have great self-confidence in my ability to succeed academically at the university,” etc. (based on Bennett 2009). The same response options as for the indicators for ICT skills were provided.

Second, a Likert scale to measure the extent to which a student is “vocation directed” was used (Profor) (Vermunt 1994). It contains five items such as “What I want to acquire above all through my studies is a professional skill,” “the main goal I pursue in my studies is to prepare myself for a profession,” etc. and could be answered with the same response options as the academic self-perception scale.

A CFA was conducted on the items intended to measure academic self-perception and being vocation directed.

Third, to measure the attitude toward scientific research, a Likert scale was developed with 12 items, such as “Scientific research is fun,” “I would enjoy school more if they did not bother us with scientific research,” etc. A scale used by Cheung (2009) concerning the appraisal of chemistry by secondary school students, was followed, but the items were adapted for the appraisal of scientific research (attit_science) (see Fig. 2).

Fourth, 13 survey items were included that gauged the students' intentions regarding their later professional life. Example items include “In my professional life I want to conduct scientific research,” “In my professional life I want to teach,” and “In my professional life I would prefer to work with people.” Factor analysis showed two scales: one refers to the intention of a student to become a researcher and the second to the intention to pursue a career other than research.

The hypothesis was that students who are more research-oriented will also have a higher level of ICT skills and use ICT more often than

other students. It was considered that this relationship might not be equally strong for all study disciplines, and therefore items to measure the extent to which students themselves are convinced that ICT is necessary for a scientific researcher were included. This information was collected with nine items such as “Today a scientific researcher cannot work properly without a computer,” “A scientific researcher should be capable of working properly with database software,” etc. (ICT_science). Factor analysis has revealed that these nine items form a good scale.

Contextual Variables

Research has shown that there are still factors that might create inequality of opportunities for some categories of the population (see section “[Introduction](#)”). Former research indicates the importance of gender, domain of study, taking an ICT course in secondary school, attending classes at university where a computer is used, and the education level of parents for the development of ICT skills and the frequency of ICT use by students (Verhoeven et al. 2010; De Wit et al. 2012).

Gender is included as dummy variable (female = 1, male = 0). With regard to the domain of study, it was expected that science and biomedical students (score = 0 for the dummy ‘Human’) will be more skilled in and more engaged in ICT activities than humanities students (score = 1 for the dummy Human). Having attended classes dedicated to ICT in secondary school and at university might also stimulate students’ ICT skills and frequency of ICT use. Two dummy variables (one for secondary school and one for university) are included in the models (0 = did not attend at least one ICT class, 1 = did attend at least one ICT class). At the university, this dummy refers to attending classes where a computer is used by the students.

Like many other opportunities in life, living in a well-to-do family creates more opportunities for easy and comprehensive access to ICT at home. Belonging to a particular social class creates or diminishes opportunities. While it is recognized that social class is a complex concept, the education level of the parents was chosen as a crude

indicator of social class. Students with at least one parent with a college or university degree were coded 1 on the dummy variable HEpar, while 0 refers to other students.

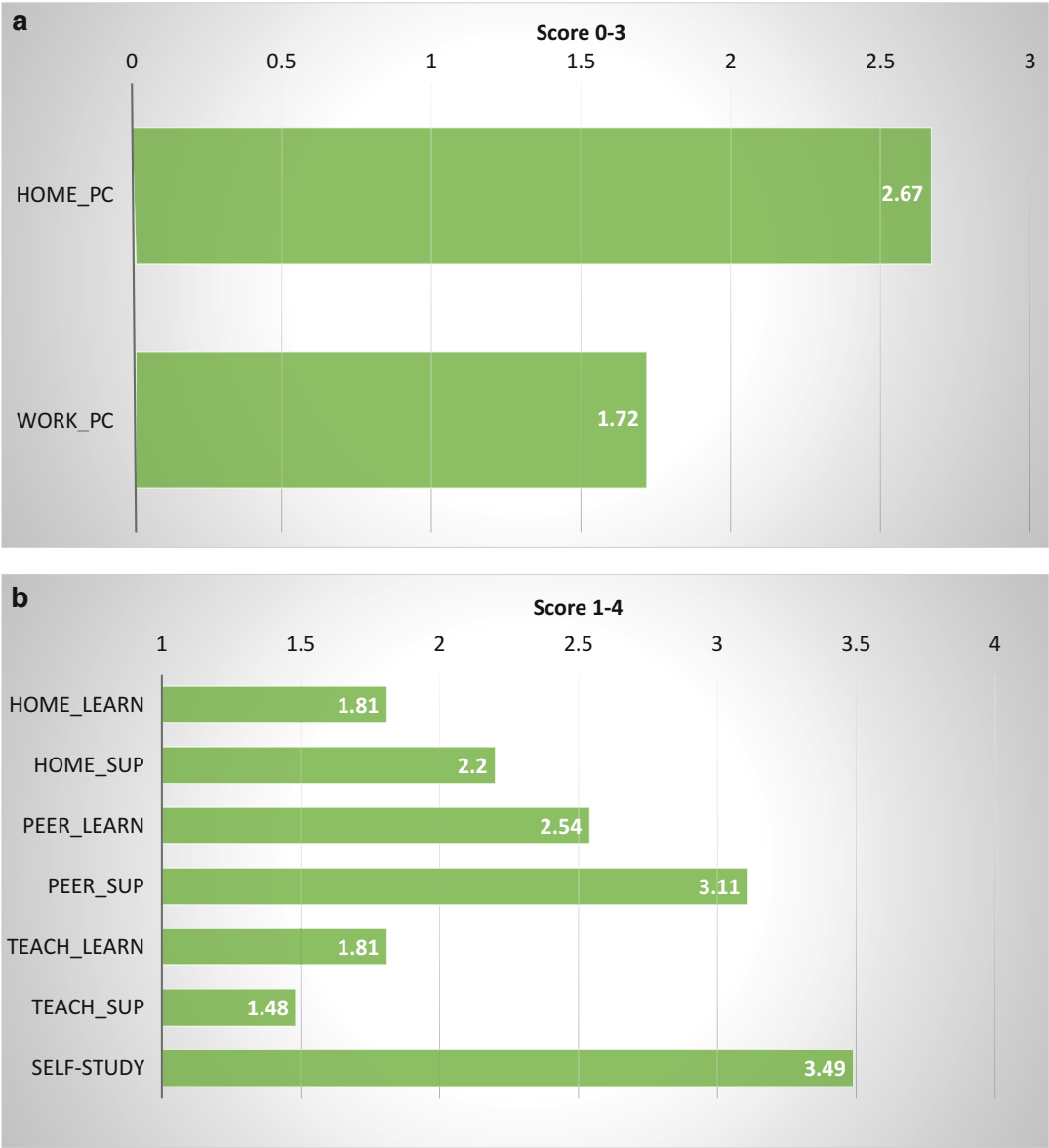
In the next sections, regression analyses are used to test the hypotheses.

Short Overview of the Main Variables

Before examining the results of the analyses, this section presents a short overview of the access of students to computers and the Internet, their learning experiences, and their attitudes toward scientific research.

A computer is a basic equipment for a student today: of the students surveyed, 99.5% of those living in rented accommodation and 99.7% of those living at home use a computer. Of the latter, 27% share this computer with another person, whereas among students living in rented rooms, only one student does. Of the computers that are at the disposal of the students most of the time, about 88% are laptops, 7% are desktops, 3% notebooks, and the rest netbooks or tablets. All the students, except one, have access to the Internet in their room and/or at home. Some 82% of the students living in rented accommodation have broadband Internet access both at home and in their rented accommodation, whereas the students living at home always have a broadband connection at home. It should also be noted that the student without a connection in his room or at home can use the Internet, as the university provides many places where students have free access to PCs and the Internet and all students receive an e-mail address from the university.

Knowing that 85% of the students have at least one parent with a higher education diploma, it can be expected that use of a computer and the Internet is self-evident for most of these families (see Fig. 3a). The use of a PC at home by parents and siblings gets an average score of 2.67 out of 3, and 89% of the parents of these students and 90% of their siblings use a computer at home. Some 77% of the fathers and 63% of the mothers of the students also utilize a PC at work (score 1.72 out of 3). This shows that the use of a PC belongs

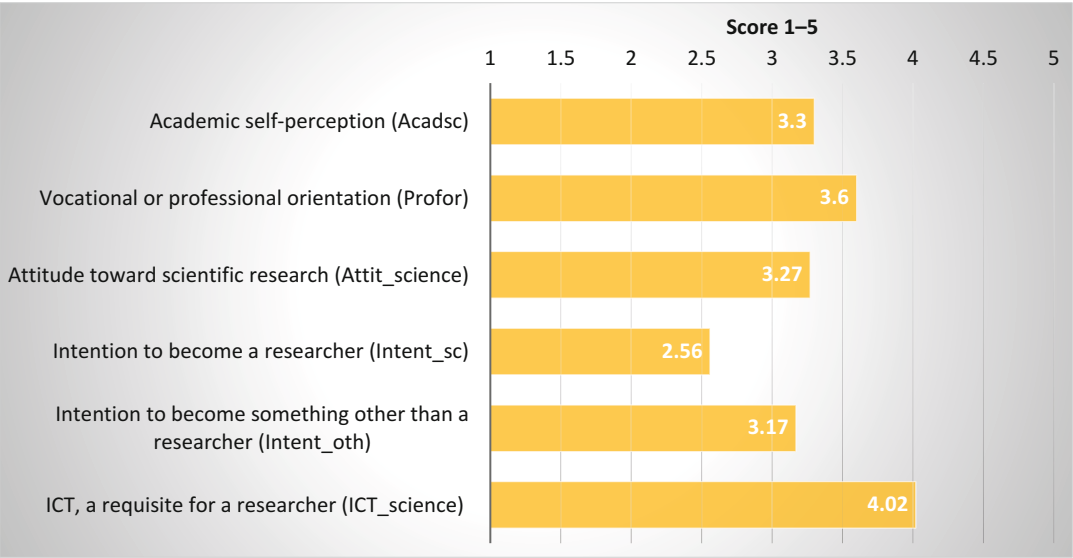


Predicting ICT Skills and ICT Use of University Students, Fig. 3 (a, b) Average score of ICT learning experience scales (Verhoeven et al. 2016, p. 86)

to the daily life of most of these students and their families. Many of them started using a PC at a young age: the average age is 11.91 (std dev = 2.46); a quarter of them were 10 or younger.

Nevertheless, this does not mean that students believe they learned most about computers and the Internet from family members. They believe

that this knowledge is mainly the result of self-study. They consider the second most important informant about ICT is their peers and the third their teachers and their family. When students need support for solving PC or Internet problems, they first ask their peers, second their parents and/or siblings, and third all types of teachers in secondary school and at the university.



Predicting ICT Skills and ICT Use of University Students, Fig. 4 Average score of academic and scientific research orientation scales (Verhoeven et al. 2016, p. 86)

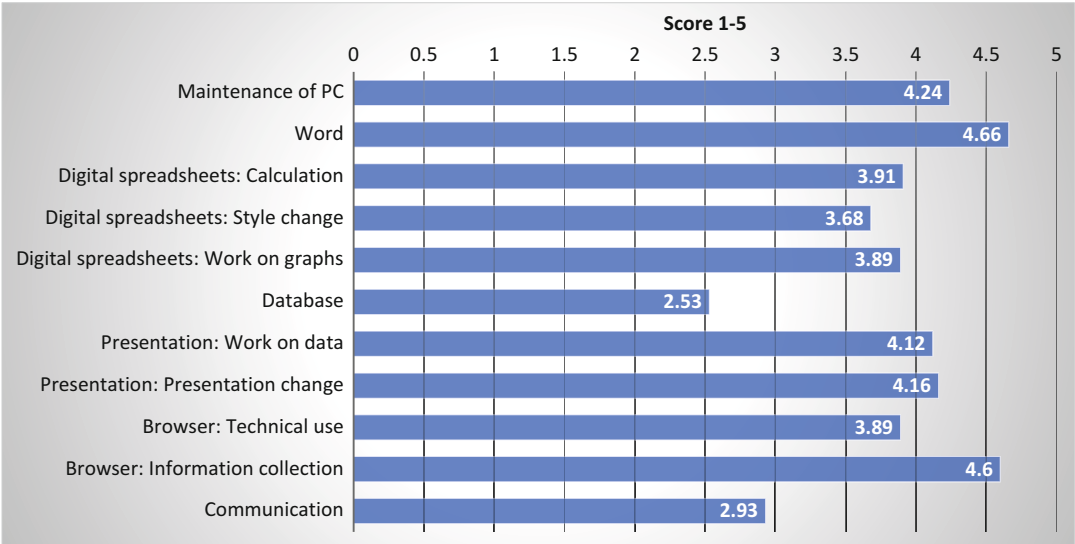
Most students attended an ICT course in secondary school – only 15% did not. At the university, some classes focus on special computer programs, but not on the basics of ICT. During the semester when the interviews were conducted, 53% of students attended one or more classes where students work on a PC. For 50% of these students, this happened weekly, for 20% several times a week, and for 30% monthly.

Scientific research is a positive factor, though a score of 3.27 out of 5 is not very high (see Fig. 4). To become a scientific researcher is not a priority for many students (score 2.56 out of 5). This might be the result of the knowledge among students that in order to become a researcher at the university a candidate should achieve higher than average. Moreover, at this stage of their education, students do not always have a clear picture of what a researcher is supposed to do. They are more interested in becoming a consultant, a teacher, a manager, or something else than a scientific researcher (score 3.17 out of 5). Nevertheless, most students are convinced that a scientific researcher cannot function properly without sufficient knowledge of the basic ICT skills (score 4.02 out of 5).

Learning Experience and Identity Commitment as Predictors for ICT Skills

It would seem safe to suppose that (at least some) ICT skills are widespread among students. After all, PCs are present in primary and secondary schools, and most students have already had to carry out tasks using a computer and the Internet at home. Writing papers, searching the Internet for a purpose, and making presentations are the daily practice in secondary schools.

Therefore, it is expected that most students at university would be convinced that they could work with a word processor, search the Internet, and make a presentation. Figure 5 confirms this expectation. It is clear that most students know how to work with a word processor (score 4.66 out of 5) and are convinced that they can do a search on the Internet (4.6 out of 5). A large proportion of the students are certain that they can maintain a computer (score 4.24 out of 5), change the style of presentations (score 4.16 out of 5), or work on the data of a presentation (score 4.12 out of 5). However, they feel they are less capable of making use of the technicalities of a browser (score 3.89 out of 5) or working with



Predicting ICT Skills and ICT Use of University Students, Fig. 5 Average scores of ICT skills (Verhoeven et al. 2016, p. 84)

digital spreadsheets. With regard to the latter, they believe that they are better at making calculations (score 3.91 out of 5) or working on graphs (score 3.89 out of 5) than making style changes (score 3.68 out of 5) in spreadsheets. In comparison with the former skills, most students are less familiar with the more special types of communication (score 2.93 out of 5). It should be stressed that communication skills are not about chatting or participating in SNS, because only 4% of the students did not chat on the Internet this academic year and only 8% did not use a SNS. The students are the least familiar with databases. Most students have only some vague knowledge of this subject, and 25% of them do not know anything at all about it.

Can learning experience and identity commitment explain some of the knowledge level of these eleven ICT skills? Neither model is very strong, but both show many significant predictors for ICT skills. Learning experience can explain 29% of the variance in the computer maintenance skills of students and 25% of the variance in the skills to use the technicalities of a browser. However, learning experience explains only 19% or less of the variance in all other ICT

skills, with the contribution being the weakest for word processing skills (6.2%) and the two skills linked with presentation programs (5.4% and 5.6%). These skills are widespread among the students (see Fig. 5).

Of the ten independent variables that are directly linked with the learning experience of the students, two contribute significantly to the explanation for all ICT skills. The strongest of the two is self-study, followed by age at the first experience of using a computer. The general pattern is that students who score high for self-study also score high for all ICT skills. However, the age when students first used a computer had negligible effects (although statistically very significant) on their ICT skills. The other forms of learning experience help little in better predicting ICT skills, except for the skills to use a spreadsheet, a browser, and a database. The more students have learned from their teachers, the higher they score for spreadsheet and database skills, although self-study is here also deemed more important than information from teachers. Some relationships are hard to understand. First, the more students have learned from their peers, the less they score on changing styles and working on graphs in

spreadsheets. Second, the more support students receive at home, the lower they score for the skills to work with a browser. These negative relationships need more research to understand why they develop in this way.

Contextual variables also play an important role. Except for word processing, female students score lower than male students for all ICT skills, a phenomenon that is often observed. Students who participated in an ICT course in secondary school score higher than other students for 9 of the 11 ICT skills. Humanities students score significantly lower on spreadsheet skills and word processing skills than science students do. Why students in the field of humanities score higher than science students for database skills is not immediately clear. This is also true for the relationship between higher education level of one of the parents and knowledge of ICT skills. Contrary to the expectation, students whose parents took higher education do not score higher for ICT skills. Additional research will be needed in order to explain this unexpected finding.

The second model, identity commitment, is weaker than the first. Nevertheless, it does unveil some interesting predictors for ICT skills. Some 20.3% of the variance in the technical use of a browser can be explained by this model, as can 17.6% of the variance in the maintenance skills of students. The model also explains between 16.3% and 15.1% of spreadsheet skills. Less variance is explained for the other skills (between 10.1% and 3.2%).

Regression analysis shows that the more students believe that a scientific researcher needs a good knowledge of ICT skills, the more they know about the different ICT skills. This is also true for students who place a high value on scientific research, but not for all ICT skills, notably style changes in and calculation skills with spreadsheets and working with databases. Contrary to the expectations, the intention to become a researcher only positively predicts competence with style changes in spreadsheets, and the intention to become something other than a researcher

only predicts the ability to work on data in a presentation program and in communications. The predictive power of these variables is below the expectations.

A positive academic self-perception and a high vocational orientation were expected to contribute to a better knowledge of ICT skills, because ICT might be helpful for study and research. This is shown to be only partly true. The higher the academic self-perception of students, the better knowledge they have of the skills to work with a word processor, to do calculations or work on graphs in spreadsheets, and to collect information with the help of a browser. When students are more vocationally orientated, they think they are more capable of making style changes in spreadsheets or working with databases or with presentation programs.

Again, similar to the first model, contextual variables provide important predictors for the ICT skills of students. Gender is the strongest predictor of all the variables in this model, except for word processing. Female students are less acquainted with ICT skills than male students. Students who attended an ICT course in secondary school score higher for ICT skills (except for information collection and communication) than other students. Humanities students seem to know less about working with spreadsheets or a word processor than science students, but have a better understanding of databases. For other ICT skills, there is no difference between the two groups.

Students whose parents did not graduate in higher education believe they have a better knowledge of how to handle some of the technical aspects of a browser than other students do, but this is the only skill where a difference between these two groups can be found. The ICT head start that students of the more privileged families might have had does not show at the university. In addition, no differences are found with regard to the knowledge of ICT skills for students who did or did not attend an ICT course at the university during the semester when the survey was conducted.

Learning Experience and Identity Commitment as Predictors for the Frequency of ICT Use

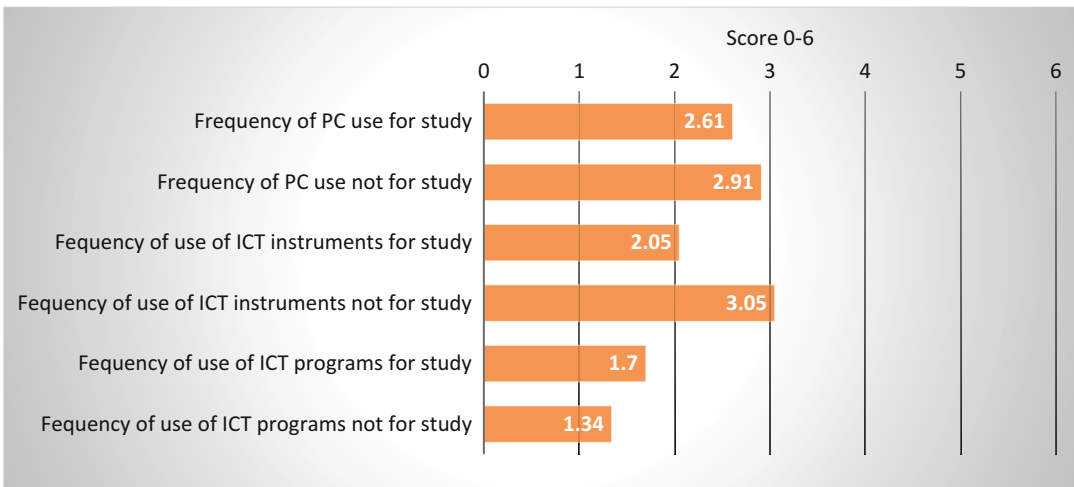
Turning to the frequency of ICT use instead of ICT skills, both models were tested again as predictors. Figure 6 reveals that computers are more frequently used for purposes other than study (score 2.91 out of 6) than for study (score 2.61 out of 6). This is also true with regard to the use of ICT instruments (respectively, scores of 3.05 and 2.05). However, students do use ICT presentation programs more frequently for study (score 1.7 out of 6) than for non-study purposes (score 1.34 out of 6).

Figures 7 and 8 show in more detail that the majority of students uses computers daily, but mainly for non-study purposes. More than four fifths of the students surf the Internet daily for fun, and about three quarters send e-mails to friends daily. Chatting is also popular: six tenths do this daily for fun. These figures are much lower when they are in connection with study: respectively, 54%, 51%, and 29%. Other activities, such as downloading music or films, participating in newsgroups, writing blogs or wikis, and

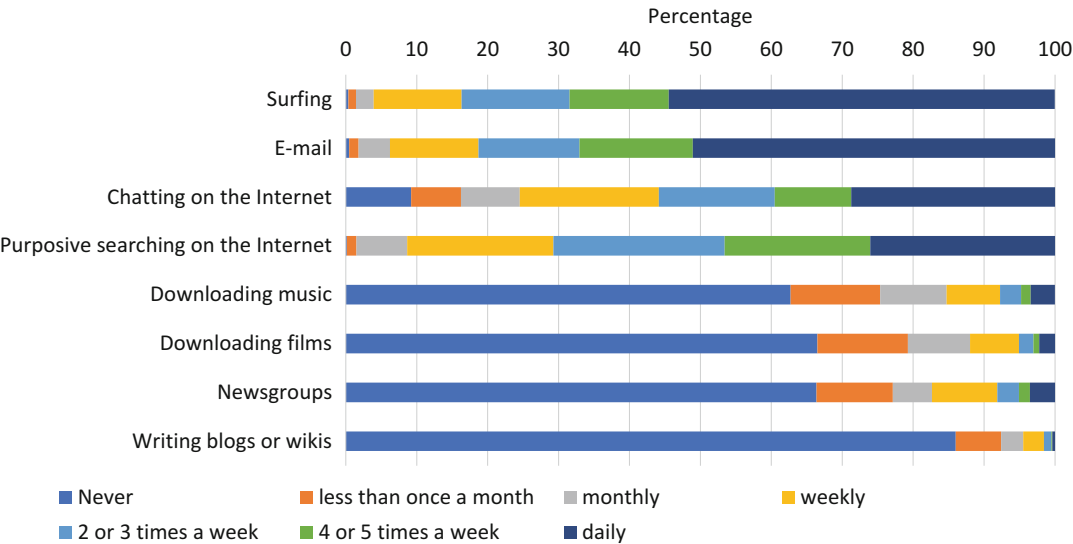
playing games, are less popular, even when they are not related to study purposes.

A similar varied picture is found for the frequency of use of ICT instruments and programs (not shown in the figures). For instance, computers and the Internet are used daily by 93% of the students, but an e-reader was never used by 92% of the students during this academic year, and an iPad or tablet by only 76%. Most students used the local virtual learning environment (98%), a word processor (95%), SNS (86%), or a presentation program (81%) in this academic year for study; the figures for non-study purposes are, respectively, 22%, 81%, 82%, and 34%.

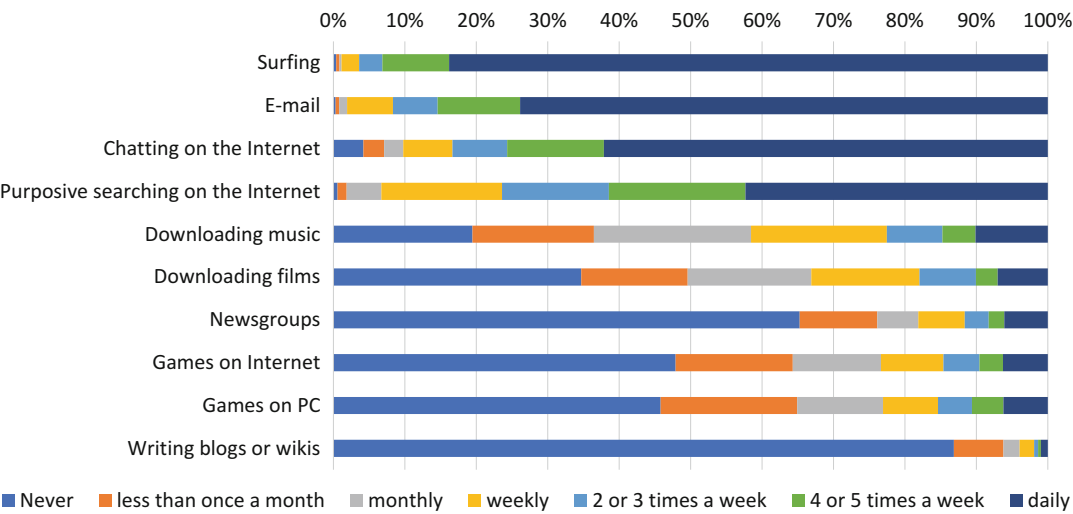
Given this varied picture of the frequency of use of computers, ICT instruments, and ICT programs, the question is whether the two models can help to predict the variation. The learning experience model does not explain a large proportion of the variance of the frequency of use, but as was the case with ICT skills, it provides some significant variables that allow a better prediction of the dependent variable, namely, PC use for non-study purposes (17.5%) and the use of ICT programs for study (11.5%). For all other dependent variables, the proportion of explained variance is 6.3% or lower.



Predicting ICT Skills and ICT Use of University Students, Fig. 6 Average frequency of ICT use by bachelor's students (Verhoeven et al. 2016, p. 85)



Predicting ICT Skills and ICT Use of University Students, Fig. 7 Frequency of computer use for study (Verhoeven et al. 2016, p. 91)



Predicting ICT Skills and ICT Use of University Students, Fig. 8 Frequency of computer use not for study (Verhoeven et al. 2016, p. 91)

With regard to the frequency of PC use, it is remarkable that the age at the time of first using a computer and self-study are significant predictors for frequency of use for non-study purposes, but not for study. The younger the students were when they started using a computer or the more they

invested in self-study, the more they use a PC for non-study purposes. Peers also play an important role, both for study and for non-study purposes: when students learned from peers and/or are supported by peers, they spend more time on a PC. Two of the contextual factors have some

meaning for computer use (both for study and non-study purposes): women use a PC less than men do, and humanities students use a PC more frequently than science students do. ICT courses in secondary school and the education level of parents, however, do not contribute to a better prediction of PC use.

The prediction of the frequency of using ICT instruments for both study and non-study purposes can be significantly improved by two variables. Again, these are the starting age of computer use and peer learning. For non-study purposes, the domain of study and peer support can be added: students in the humanities and those who enjoy more support from peers have a higher chance of more frequently using ICT instruments for non-study purposes. Other variables do not seem to have a significant meaning for the frequency of use of different ICT instruments.

The frequency of use of ICT programs for study and non-study purposes is more sensitive to the variables of the learning experience model. A young age of first using a PC, support from peers, and self-study allow better predictions for the frequency of use of ICT programs. In addition, the domain of study of the student creates better predictions: ICT programs will be used more by science students than by humanities students for study purposes, but for non-study purposes, the reverse is true. It is also shown that women use ICT programs less frequently for study than men do and that students who learned more from teachers and peers about ICT will use ICT programs for study more often. Although attending university courses in which a computer is used does not explain significantly the mastering of ICT skills (see section “[Learning Experience and Identity Commitment as Predictors for ICT Skills](#)”), this variable is a significant predictor of the frequency of the use of ICT programs for study. Moreover, regression analysis shows that it lets the difference between male and female students disappear, which implies that the study situation contributes to a more frequent and more gender-equal use of ICT programs.

The second model expresses the relevance of identity commitment for the frequency of the use

of a PC, ICT instruments, or ICT programs by students. Here, two important factors of identity commitment are the students’ professional orientation (Profor) and their belief in their own academic capacities (Acadsc). However, it turns out that this model does not have much explanatory value for either the frequency of use of a computer, ICT instruments, or ICT programs.

The identity commitment model explains 5.3% of the variance in frequency of PC use for study and 10% for non-study purposes. All other R^2 values are smaller or almost equal to zero.

In the identity commitment model, the best predictor for the frequency of use of a PC is the conviction of students that a researcher needs sufficient ICT knowledge. The more they believe this, the more frequently PCs are used, both for study and non-study purposes. Frequent use of a PC for study is also supported – and this is not what was expected – by a stronger intention of the student to become something other than a researcher and by a stronger orientation toward a profession. Frequent use of a PC for non-study purposes, in turn, is supported by the belief of a student that ICT is needed to carry out scientific research. In addition, the contextual factors are good predictors for PC use. Female students spend less time on a PC than men, and science students less time than humanities students.

Students who think that researchers need appropriate ICT knowledge will use all kinds of ICT instruments more often for both non-study and study purposes than those who do not hold this opinion as strongly. This is also true for students (as far as they need the instruments for study purposes) who are more vocationally orientated. Moreover, students with a positive attitude toward research will more frequently use these ICT instruments for study than other students will. However, unexpectedly, students who are more inclined toward becoming a researcher will use all these ICT instruments less often. With regard to non-study purposes, the more positive students are about their academic capabilities, the more they use ICT instruments; humanities students will use ICT instruments more frequently than science students. It should

be noted that gender and having attended an ICT course in secondary school are not adequate predictors here.

The use of ICT programs for both study and non-study purposes can be predicted by ICT_science and gender. Students who believe that researchers need a good knowledge of ICT will use ICT programs more than other students will. When programs are used for study or non-study purposes, the scores for male students are higher than for female students. Students who are aiming for an occupation other than a researcher also use ICT programs more frequently for non-study tasks than other students. It should be noted that ICT course experience in secondary school and the education level of the parents do not contribute to making better predictions for the frequency of using ICT programs.

Conclusion

In this article, two hypotheses regarding the ICT skills and the frequency of ICT use by university students were presented. In line with Dewey's learning theory, the first hypothesis is that a positive ICT learning experience at home, in school, and with peers will contribute to a higher level of mastering ICT skills and a more frequent use of ICT among bachelor's students (the learning experience hypothesis). The second hypothesis is based on the use of ICT in research and the similarity between the structure of information systems and scientific research. From this, it was hypothesized that students who strive for an identity commitment that is directed toward scientific research will be more inclined to learn ICT skills and show a higher frequency of ICT use. Both hypotheses are tested with the inclusion of some important contextual variables: gender, domain of study, ICT course in secondary school or at the university, and the education level of parents.

The explanation of different levels of ICT skills provided by the learning experience model is confirmed, but not very strongly overall and not equally for all types of ICT skills. The model can explain the largest proportion of the variance

in maintenance of a computer and the technical use of a browser. In descending proportion of explained variance, these two skills are followed by the three of working with a spreadsheet, communication skills, information collection with a browser, working with databases, two forms of working with a presentation program, and working with a word processor.

The best predictors for most of the skills are the age of the students when they first started using a PC (the lower the age, the higher the scores), self-study, gender (men score higher than women), and having attended an ICT course in secondary school. Instruction from teachers is important for working with spreadsheets and databases. It is also noteworthy here that the use of a PC at home and at work by parents and siblings, what the student learned of ICT at home, and the support of peers and teachers do not play a significant role, although research has shown that these factors are important in primary and secondary schools (Vekiri 2010; Aslanidou and Menexes 2008; Barron et al. 2010; Zhao et al. 2010).

The learning experience model also explains some of the variance in the frequency of ICT use. It explains 17.5% of the variance in the frequency of PC use for non-study-oriented tasks, but for all other frequency-related dependent variables, the proportion of explained variance is much smaller.

Predictions of the frequency of ICT use can be improved taking into account the age when students started to use a PC (the lower the age, the higher the use), self-study (only for non-study purposes), domain of study (humanities students mostly score higher than science students), and gender (women score lower than men). Peer support is a significant predictor for the frequency of computer use and of ICT programs, and this applies to both study and non-study purposes. What had been learned at home is not recognized as a factor that could predict the frequency of ICT use by the students. This is the same for ICT courses attended in secondary school and at the university or the education level of the parents.

The identity commitment model also explains parts of the variance in the ICT skills of students. The explained proportion of the variance,

however, is very different for each of the ICT skills. This model explains two fifths of the variance in the technical use of a browser, but for all other ICT skills, the results are lower, sometimes substantially so. The most important predictors of this model are the belief of students that researchers need an appropriate knowledge of ICT, a positive attitude toward scientific research, gender (lower scores for women than for men), and having attended an ICT course in secondary school. The other explanatory variables have very diverse impacts. Each of them improves the prediction, but for very different ICT skills. The reasons why these differences occur are unclear and require more research. It should also be mentioned that the intention to become a researcher is not a strong predictor: only the skill to perform style changes in spreadsheets seems to be better developed among research-oriented students.

The identity commitment model is less successful in explaining the frequency of ICT use. Only one explanatory factor plays a significant role in the explanation of the six dependent variables, i.e., the belief of the students that researchers need ICT. The more students think that a researcher needs a good knowledge of ICT, the more frequently they use a PC, ICT instruments, and ICT programs – and this applies to both study and non-study purposes. The other factors do not have the same predictive value, and their value differs for each of the dependent variables. In other words, the hypothesis that students who want to become a researcher will score higher for using ICT is not supported by the data. On the contrary, students who want to become a researcher do not show more frequent use of a computer or ICT programs, and they actually use ICT instruments for study less frequently than other students do.

In short, the learning experience hypothesis and the identity commitment hypothesis are both only partially confirmed by this research. In general, however, it can be concluded that a relationship does exist between the ICT learning experience, the research-oriented identity commitment of bachelor's students, and their command of ICT skills on the one hand and the frequency of use of a computer, ICT instruments,

and ICT programs on the other. However, this is a very diversified relationship, which is not always equally strong for all aspects of ICT skills and ICT use. To better understand these differences, future research will have to dig deeper into the particularities of divergent ICT skills and ICT uses.

Cross-References

- [Computers in Secondary Schools](#)
- [Digital Citizenship, A Sociocultural Snapshot](#)
- [Digital Literacy, Creativity, and Autonomous Learning](#)
- [Innate Abilities and Learning in Higher Education](#)
- [IT in Educational Institutions, Planning and Development of](#)
- [Literacy and Technology](#)
- [Mobile Computing and Mobile Learning](#)
- [Social Media for Tertiary Education](#)
- [Social Networking in Higher Education](#)
- [Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools](#)
- [Tablet Use in Higher Education](#)
- [Teacher–Student Relationship and Online Social Networks](#)

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Preferences

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Primary School Classroom Writing Interventions Using Technologies

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Synonyms

[ICT tools](#); [Personalized learning](#); [Self-regulation](#); [Teaching-learning process](#); [Writing](#)

Introduction

Primary school classrooms are filled with diversity that constantly challenges the teacher's role as facilitator of the development of children's writing process skills. However, many teachers feel unable to help their students overcome

their writing problems and feel that students don't like these activities (Graham et al. 2007). As a result, the reasons for these difficulties, presented by teachers, highlight the lack of training, time, or skills to respond to the current literacy needs of children, where writing communication can occur in analog or digital formats (Araújo 2017; Graham and Harris 2013).

In recent years we have witnessed rapid changes and advances both in the writing process and in the resources used for writing, strongly marked by the present and dynamic role of ICT. These have created opportunities and challenges for the development of children's writing, whether through social networks, facilitating access to information, or by diverse forms of writing (Buckingham 2013; CAST 2011; Edwards-Groves 2011; Tavares and Barbeiro 2011).

Today, children are becoming experienced users of digital communication and are increasingly familiar with digital and online writing in a variety of contexts (smartphones, tablets, PCs). This form of writing began by using different channels (phone, email, and Internet) and has assumed different modalities (sounds, gestures, iconographic symbols, animations or even the abbreviation of words or phrases) that are accessible to students at an earlier age (Kilpatrick et al. 2014; Graham and Hall 2016). Thus, writing appears more and more as a social act in a network that has become a necessity in our world today (Graham and Rijlaarsdam 2016; Moore and MacArthur 2016; Prensky 2005; Selywn et al. 2010).

In this context, writing implies the in-depth knowledge of the various contexts and situations of written communication, including the use of technologies (Bazerman et al. 2017). Currently, in a semiotic perspective and multiliteracies, writing assumes a multidimensional and dynamic nature that integrates the use of linguistic, visual, spatial, gestural, and audio characteristics, as well as emphasizes the role of design (in production and presentation) in the construction of textual meaning, where visual representations of ideas gain space (CAST 2011; Campbell and Ballast 2011; Cope and Kalantzis 2012; Rose et al. 2005; Rose and Meyer 2006; Wolf et al. 2016).

Technologies can also help the teaching-learning process by promoting motivation; facilitating the access; monitoring and evaluation of knowledge by the student and teacher; and differentiation and pedagogical alternatives to allow the involvement of the school community with the world and also to facilitate administrative work in the school context (Araújo 2017; MacArthur 2009).

The use of technological web resources in writing can, for example, facilitate immediate access to information; the possibility of exploiting individual interests and/or clarifying real-time doubts and exploiting various communicative spaces (e.g., interpersonal, virtual, digital, and textual) or acquisition and collective intelligence. However, they also present some constraints, such as: difficulty in analyzing, selecting, and processing information that can lead to cognitive overload and disorientation. Therefore, students need to learn (e.g., how to locate, evaluate, and select or synthesize relevant information) (Leu et al. 2004; Jenkins 2006). Also the use of digital resources (e.g., multimedia) can facilitate access to multiple forms of communication (e.g., text, image, audio narration, and animations/videos) (MacArthur 2009; Prensky 2005) and reduce the cognitive load in working memory and improve information processing, which enhances the understanding of the transmitted message together with the tools and applications that facilitate the construction of knowledge and reflection (e.g., semantic networks, search engines, visual representation tools) (Mayer 2005; Vue et al. 2015).

The fundamental and powerful role of ICT in classrooms is no longer questioned, regardless of the many different forms of action. In the light of the research, we know and recognize the benefits of several technological resources such as word processor, word predictors, grammatical or speech synthesizers, digital books, or blogs (Thompson et al. 2016). Thus, it has a set of facilities that ICTs provide, in particular, immediate feedback, the presentation of information through a variety of multimedia formats [that can favor the visual and aural view], allow the sharing of activities and the development of collaborative and interactive practices, enable visually attractive writing, allow for the

reorganization of the text, contribute to the dissemination of information and develop audiences in the process of writing texts and writing self-esteem (Araújo 2017; Thompson et al. 2016; Smedt and Keer 2014).

Thus, since the process of writing is a constantly changing act of communication, the use of ICT is not only limited to its use as a tool but to a change in the way we understand writing and its learning in a constantly changing social context. Despite this, there is, on the one hand, a resistance or a lack of focus on the use of ICT in education (MacArthur 2009); on the contrary, there is a very strong relationship established between ICT and school or professional writing (Tavares and Barbeiro 2011). However, many teachers feel insecure in teaching the writing process using technology (Araújo 2011, 2017; BECTA 2004, 2007). The impact of writing interventions using technologies in the inclusive primary classroom context, where teachers try to adapt the teaching process to the characteristics and needs of all students, has also been lightly studied. Technologies in writing can have a positive or negative effect on learning depending on how well teachers and students take advantage of their abilities, often influenced by the type of instruction in the learning activities with the technologies and using these resources (MacArthur 2009).

Several authors have referred to the need for more research on writing, both digital and handwriting, by children and using ICT (Peterson-Karlan 2011). For the above reasons and because we recognize the need to carry out studies that explore and exemplify how to take advantage of the potential of using ICT in writing practices in inclusive primary education classrooms, a practical example is presented below explaining possible steps, processes, and activities that can be performed by teachers in the classroom.

Strengths and Challenges of Using ICT in Classroom Writing Contexts

It is relevant to know the strengths and challenges of using these resources in the classroom before using ICT in classroom teaching interventions

(Bazerman et al. 2017). In this way, it will be possible to make more informed decisions and anticipate procedures to deal with the possible challenges of the difficulties that can be encountered.

Considering the inclusion of ICT in writing practices in the primary school classroom context and the new environments and formats of written communication, an exploratory study was carried out with a proposal for the exploration of classroom writing intervention in opinion essays (linear and multimodal, using, i.e., images, sounds, and text) by 4th grade Portuguese students considering the implementation of an inclusive curriculum, which will be presented as an example of how to operate the use of ICT in classroom writing interventions, and the articulation of theoretical recommendations for the learning process of writing in the classroom context using the ICT potentialities to promote improvement of writing quality, particularly of opinion essays.

Phase I – Definition of Theoretical Foundations

The planning of classroom-based interventions using ICT to improve writing skills should involve addressing three key areas: *The pedagogical area* represents the options regarding the strategies and methodologies to adopt, i.e., setting goals, authentic writing contexts, dictation of students' texts, writing-reading relationships; active or expositive methodologies; use of strategies that promote the management of behaviors and thoughts by the student to reach a certain goal – self-regulation, or learning by trial and error; individual and/or collaborative teaching. The *knowledge area* represents the knowledge about the subjects involved in the students' learning processes, i.e., linear and multimodal writing process; explore multiple means of representation such as visual or auditory; and the process of teaching writing. And the *ICT area* represents the possibilities of using ICT resources and the knowledge of the potentialities in the process of teaching learning, i.e., word processor; spell checker; mental maps; speech synthesizers; and others (Araújo 2017; CAST 2011; Mishra and Koehler 2006). The articulation between these

three areas will guarantee the previous knowledge of the teacher on the subject to address the way to operationalize learning to promote the learning process of the students and the options of the resources at their disposal, while being aware of the necessary care according to the various available options. The anticipation of possible difficulties or constraints will allow the teacher to plan possible alternative solutions to deal with situations that may arise (Araújo 2017). For example, if a specific program is going to be used in the classroom, it is important that the email and password that allow for the installation of applications or programs on the devices is safe which is especially important when using devices from families.

As previously mentioned, the learning process of writing, linear and multimodal, in the twenty-first century is more complex and challenging than the different forms of writing, with multi-literacies (Cope and Kalantzis 2012; Kress 2003), and writing contexts such as the need to change the “traditional” pedagogical practices of a society lacking in ICT resources for innovative practices that create new learning opportunities (Kilpatrick et al. 2014). It is, therefore, advisable to include in the current practices, the approach so that the teacher can create new opportunities of essential aspects such as: creativity, communication, and collaboration (Bazerman et al. 2017; Buckingham 2007; Graham et al. 2012; Jonassen 2007).

Universal Design Learning (UDL) suggests that it is essential to provide access to multiple means of representation (perceptions, language and symbols, and comprehension), multiple means of action and expression (physical action, expressive skills and fluency, and executive functions), and multiple means of engagement (recruiting interest, sustaining effort and persistence, self-regulation) (CAST 2011), for more information see: <http://www.cast.org/>.

Currently, intervention with the greatest scientific evidence for the promotion of writing is the Self-Regulated Strategy Development model (Harris 1982). This specific framework for an instructional strategy promotes explicit teaching and guides students in the writing process through self-regulation strategies such as: goals-

settings, self-monitoring, self-talks, and self-reinforcement. SRSD is composed of six stages: active background knowledge, discuss it, model it, memorize it (mnemonic and practice the strategy), support it, and independent performance. These steps are not linear, and a step can be returned to whenever necessary. Over time there is a progressive and gradual transfer, according to the competences and abilities demonstrated by the student, of the responsibility of the learning process of the teacher to the student (Harris et al. 2008). For more information about SRSD, please consult <http://www.thinksrsd.com/>, <https://course.srsdonline.com/cart/>, for example.

Finally, it is also recommended to promote a teaching process that promotes the development of actions in students that stimulate their learning, gradually increasing its complexity in order to make them autonomous in the application of acquired knowledge and skills, suggesting the use of Revised Blooms' Taxonomy (Anderson and Krathwohl 2001), namely, the promotion of activities that include remembering (recalling relevant knowledge), understanding (making sense), applying (using the knowledge), analyzing (breaking the concepts into parts), evaluating (making judgments based on a set of guidelines), and creating (innovating).

Phase II – Profile Identification of Students and Contexts

There are some factors that influence writing classroom intervention using ICT identified by researchers such as: (a) previous experience and knowledge; (b) involved community elements; (c) resources and conditions (i.e., teaching environment, methods, and strategies); (d) group management (i.e., group organization, time, individual differences, individual and group dynamics); and (e) proposed activities (i.e., proposal, implementation, and pedagogical evaluation) (Araújo 2017; MacArthur 2009; Tavares and Barbeiro 2011; Kilpatrick et al. 2014). Furthermore, researchers have reiterated the need to create explicit and context-specific responses (Harris and Graham 2016).

Gathering information on some of these factors will help in the use of strategies, methodologies,

and resources tailored to the needs, abilities, and potentials of the students and contexts in which the classroom writing intervention is developed.

The use of surveys, scales, interviews, and/or written productions to student, family, and colleagues can help in obtaining important information (e.g., Bruning et al. 2013; Graham et al. 2012). It is advisable, for example, to collect information on *students' profiles*: (a) perceptions about writing knowledge, attitudes, and self-efficacy, (b) writing performance, (c) writing practices, (d) academic course, and (e) learning profile; and *learning contexts*: (a) pedagogical practices in the classroom and at home, (b) facilitating or hindering elements, (c) interpersonal relationships, and (d) personal characteristics of group elements (Araújo 2017).

Some resources such as the following can help gathering information about the students' profiles and context, namely: Scale about students' Approach to Writing; Scale about students' attitudes and motivation, and Scale about students' self-efficacy in writing; Scale about structural elements in opinion essays (e.g., one point for the presence of each topic sentence, reasons, arguments, examples, and final sentence); writing survey instrument about writing practices; scales about approach to writing with ICT, writing attitudes with ICT, and writing self-efficacy with ICT; and essay length by word count and number of connectors. For information on the authors of these instruments, please consult Araújo (2017).

This information may be helpful, for example, for students with low perceptions of self-efficacy who generally tend to give up on tasks more easily (Araújo 2017). Therefore, knowing in advance the characteristics of learners can help define ways of approaching writing using ICT with these students (i.e., use greater enthusiasm, reinforce student successes). Also, students with reduced experience of using ICT resources may present some difficulties or need practice in writing with a keyboard or to understand the different communication spaces. Another possible example may be the observation of possible discrepancies between students' perceptions and their actual performance in writing,

since it should be approached with greater care in presenting the aspects to be improved among those who present more misconceptions (Araújo 2017).

Phase II – Goals Setting

Goal setting is an evidence-based practice in writing (Harris and Graham 2016). Thus, before the beginning of the intervention, it may be important to clearly define each student's goals to reach at the end of the intervention, which should be individualized (Araújo 2017; Graham et al. 2013). Therefore, it is possible to define a general objective: to improve the writing of opinion essays, for example, and a specific objective: the use of more diverse words, better organization of essays, or making fewer errors when essays are written, for example.

The goals selection criteria may consider the results obtained in the student's performance in the evaluation, considering the area that the students presented more difficulties in writing quality essays (Araújo 2017). However, this process must involve each student through the students' obtained feedback from the evaluation obtained in the pretest and according to the results defining the specific objective. If the student and the teacher have considered other pertinent goals, they can readjust them. The students were informed that at the end of the intervention they would have achieved their goals, looking for a commitment of the student to strive for the desired results and achieve the initial objectives. These goals can and should be adjusted and increase in complexity whenever they are achieved. This phase will help the student to think about what is intended and to anticipate behavior that will help them achieve their goals.

The students had the opportunity to observe the results obtained in the pretest, where they were asked to write an opinion text based on a question, regarding the quality of the texts produced (e.g., theme and typology; information coherence and adequacy; structure and cohesion; morphology and syntax; vocabulary repertoire; spelling) (source: Scale from Portuguese National Jury of Examinations of the Ministry of Education, 2011) and the structure of the text (number of elements

present in the text: opinion, reasons, counter-reasons, examples, and final sentence) (for more information's about these resources, please, see Araújo 2017). They also observed their perception of knowledge and attitudes in the writing of texts with and without recourse to technologies (1 = strongly disagree and 5 = strongly agree), as well as the perception of self-efficacy with and without recourse to ICT (percentage scale between 25%, 50%, 75%, and 100%), adapted from Pajares and Valiante 2006). After identifying the areas in which the students presented greater difficulties, two objectives were defined for each student, which included a general objective: improving the quality of the text and a specific objective (Araújo 2017).

Phase III – Classroom Writing Intervention

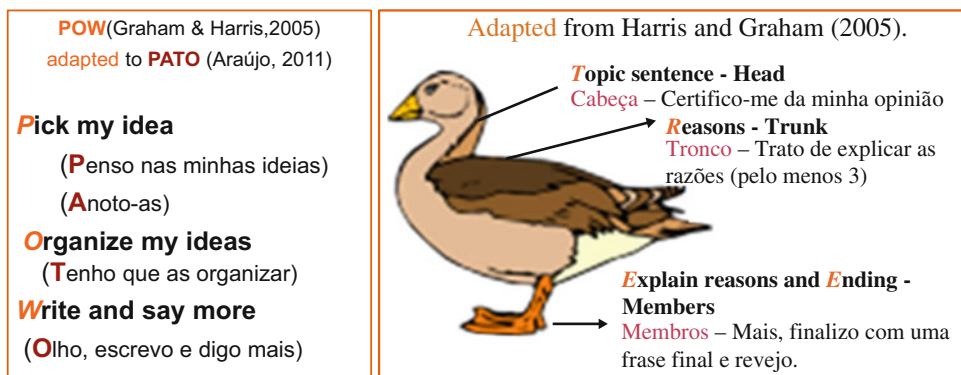
This classroom writing intervention, called SRSD + ICT model (Araújo 2017), was based on multi-based theories, especially the SRSD model, and involves evidence-based practices (defined in phase I). In interventions in a large group, attention should be given to the multiple agents involved in the classroom writing activities (considering the information collected in phase II) which is intended to be adaptable to individual and group characteristics of students.

In the same way, and whenever possible, we will seek to promote early detection and intervention in writing problems. In this way the classroom writing intervention will integrate the regulated use of ICT in the learning process of writing, both in terms of resources with potentials in the learning process of writing, using twenty-first century writing tools as defended by Graham et al. (2015).

This intervention lasted 12 weeks, with 1 weekly session of 90 min. Each session had a specific objective which will be described below:

Session 1: Exploration of knowledge about the writing process and contexts of writing, as well as textual genre and associated characteristics (classroom group).

Session 2: Discussion about what good or bad opinion texts are by observing and analyzing examples (classroom group).



Primary School Classroom Writing Interventions Using Technologies, Fig. 1 Mnemonic “DUCK” + “Structure”

Session 3: Modeling of the writing process of an opinion text by the teacher with the participation of the students from the idealization to the publication of the text. Including the use of self-talks, self-monitoring, self-assessment, and self-reinforcement (classroom group);

Session 4: Memorization of the Mnemonic “DUCK” + “Structure” (Araújo 2011) in order to facilitate the recall of key information used to remember the steps that must follow in the writing of all texts, “DUCK,” and opinion essays, “Structure,” visible in Fig. 1 (classroom group);

Session 5: Exploration and discussion of knowledge about writing (linear and multimodal) and the potentials and contexts of ICT use in writing (classroom group);

Session 6: Modeling the use of ICT in writing opinion texts, exploring tools such as: word processor; spelling checker; mental maps; speech synthesizers; and others, as well as ways of conducting research to assist in the preparation of an opinion essay (Classroom groups involved in the components of classroom writing intervention using ICT (please see, Fig. 2));

Session 7: Support practice for writing opinion essays using the ICT tools previously addressed. Reflection on the utilities, potentials, and constraints in the use of ICT resources (small groups: 3–4 students);

Session 8: Support practices for writing opinion texts, with or without recourse to ICTs,

according to the opinions of the students and the teacher (small groups: 3–4 students);

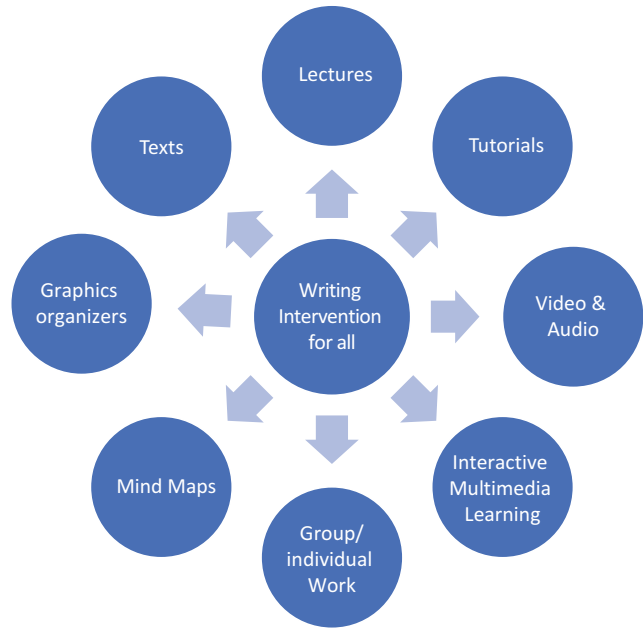
Session 9: Modeling the use of ICT in the writing of multimodal opinion texts, using rainbow mnemonic (Araújo et al. 2019), exploring programs that involve image, sound, and video editing and multimodal opinion essay writing practices, using image, video, and sound editing programs (small groups);

Session 10: Specific work in the area related to the specific objective: (a) theme and typology – identification of different types of text and characteristics; (b) information coherence and adequacy – identification of gender, grade or tense concordance, synthesis of ideas, and correction of ideas in sentences; (c) structure and cohesion – identification of the essential aspects of texts (e.g., introduction, development, and completion), reinforcement of the learning process stages, and variations, as well as the exploration of the distinction between sentences and paragraphs in a text; (d) morphology and syntax – identification of syntactic and no synthetic sentences; (e) vocabulary repertoire – construction of word families, vocabulary areas, and identification of simple and compound words; and (f) spelling – rules explanation and training/group play: identifying the rules and the correct spelling (small group/individual);

Session 11: Sharing experiences with colleagues, e.g., explanation of what they did and what they learned and reading produced texts (if

Primary School Classroom Writing Interventions Using Technologies,

Fig. 2 Components of classroom writing intervention using ICT



any). Writing practice of opinion essays in pairs (pairs); and.

Session 12: Independent practice of writing an opinion essay (individual).

It is also fundamental that, throughout the intervention, students should talk to other students in a language which is accessible and according to the language they normally use, facilitating the input of the strategies, steps, and information presented. This includes explicit thinking and communicating with students to reflect on how the strategies they have learned throughout the intervention can be transferred to other contexts. Lastly, whenever possible, the student and the teacher must focus on specific goals through the individualization of pedagogical practices (Araújo 2017).

Phase IV – Intervention Assessment

After the intervention, it is advised that students write an opinion text based on a question, which should be then evaluated in terms of quality, text structure, length, and number of argumentative connectors (posttest). It is further advised that students complete questionnaires with their opinions of the intervention and specific components

addressed in the intervention. After 6 weeks of the end of the intervention, the students should write other opinion texts that will be later evaluated in the same categories as pretest and posttest (follow-up). Subsequently, the students can compare the results obtained before, after, and 6 weeks after the intervention and verify whether they were able to meet the goals set out at the beginning of the intervention (Araújo 2017).

Students' Writing Performance

It was verified in the results of this exploratory study (Araújo 2017) with five 4th school grade classrooms in Portugal (87 students), definite improvements in students' writing performance and students' self-efficacy perceptions in writing, an increase in students' knowledge of writing, and students' knowledge of the potentials of ICT in the writing process. Similar results from previous studies confirmed that instructional writing practices promote improvements in students' writing performance (e.g., Graham et al. 2012, 2013; Prata et al. 2015; Festas et al. 2015) and ICT approaches in the writing process can produce improvements in writing performance (e.g., Tanimoto et al. 2015; Santangelo and Graham 2016). Also, the positive relationship between

the perceptions of writing self-efficacy and writing performance had already been verified by other authors (e.g., Bruning and Kauffman 2016; Pajares 2003).

The students' performance obtained in this example of ICT implementation in classroom writing intervention indicates that most of the students improved their results regarding the structure, quality, and number of linking words used in the essay opinion, resulting in improvements with greater effects than expected, exceeding those observed with the most effective interventions in writing (Araújo 2017). From the above, part of the intervention success can be attributed to the compilation of various evidence-based writing practices highlighted by Harris and Graham (2016) among other researchers (e.g., prewriting activities, explicit and direct teaching, modeling, feedback, authentic learning, peer support and review, use of self-regulation and metacognition processes, promotion of independence, reinforcement of the relationship between reading and writing).

These results reinforce the positive effect of ICT in students' writing process, already evidenced in previous studies, and self-regulated use of ICT in the process of learning to write.

Also, students' goals were able to improve their performance in writing opinion essays (98.9%) and 96.6% of students were able to improve their specific goals (Araújo 2017). In addition, the ability for students to regulate and control their learning process and to choose various writing tools and formats, as well as listening and respect for choices, previous knowledge, and individual characteristics may have contributed to their meaningful attribution, regarding their writing learning process.

In the final survey, the students identified some of the programs they liked most during the intervention. The use of writing programs (82.8% of students) and Internet use (71% of students). Among the resources used, those which presented a lower percentage were dictionaries and similar courses (28%). However, there were very different perceptions of the students according to the usefulness in ICT for writing (Araújo 2017). These differences between students are expected,

and it is consequently essential to observe and record them in the context of educational investigations, serving as a basis for further study in order to provide indicators of different forms of action by education professionals (Bazerman et al. 2017).

Therefore, the intervention allows students to control their learning, that is, regulate the use of ICT and writing strategies for the learning process allowing, reinforcing the importance of self-regulation as indicated in several previous studies (e.g., Hattie 2009; Graham et al. 2007, 2012; Graham and Perin 2007; Graham and Rijlaarsdam 2016; Harris and Graham 2016), to produce better results than when it is the teacher who performs this role. In this way, all the students experimented with different tools and had the possibility to choose whether to use a certain tool during the writing process. The possibility of being able to respect the students' perceptions of the usefulness of ICT throughout the writing process, or whether or not to use them like any other tool, was considered very positive by the students.

Reinforcing students' critical thinking about the most appropriate tools and strategies for each student present in this intervention operationalized the importance of developing this competence and building collaborative networks defended by Jonassen (2007), among others, which may have assumed with a positive aspect that contributed to the results achieved.

Finally, the students' independence in writing was stimulated and, together with the teacher, each student decided if and when to use ICT for their writing process, as well as using other forms of writing to help their writing process (e.g., auditory, visual), as advocated by several researchers (e.g., Campbell and Ballast 2011; Cope and Kalantzis 2012; Edwards-Groves 2011). It should also be noted that the ICT resources of the students' families, including computers, tablets, and mobile phones were used and that the introduction of these technologies in the classroom for writing promoted more active and proactive dynamics among students. This intervention followed the recommendations of Boyle et al. (2015) who advocates pedagogical practices guided by clear, explicit, practical,

scientifically validated, and teacher-oriented instructions according to the individual needs of the students in the class and the educational goals to be achieved.

Conclusions and Implications

It was possible to include the use of ICT in the classroom writing intervention, following the guidelines of the scientific community, which sought to respond to the profile of the student and the context, as well as to articulate methodologies and strategies of pedagogical intervention with the aim of promoting adjusted responses to all students, taking into account the individualization and personalization of learning in the classroom context. Although not all pupils were able to achieve improved writing quality of opinion texts, the results of about 99% of pupils who achieved their goals after the intervention proved superior to previously undertaken and promising interventions; however, more research is needed to articulate the modification of teaching methodologies and strategies in writing appropriate to the new resources and contexts of writing, including the possibilities of the use of ICT and multimodal writing.

As previously identified, ICT was considered as a possibility highlighting the importance of students having the knowledge and experience to help them make effective decisions to improve their skills, knowledge, and performance in writing. At the same time, the use of self-regulation strategies proved to be an asset in the progressive development of students' autonomy in the writing process, exploring the different contexts and potentialities and adjusting the school reality to the surrounding social reality. Given the promising result obtained, it is considered relevant to carry out more studies in several contexts, in order to understand the implications of interventions as suggested by the students. Finally, it was also possible to promote early detection and intervention of writing problems both individually and in groups, focusing on the individual and is adjustable to the characteristics and needs of students.

Cross-References

- [Literacy and Technology](#)
- [Teacher Education, Thinking About ICT](#)
- [Technology Enhanced Learning](#)

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Primary Schools

- [Beginnings of Computing in School Education in Australia](#)
- [Exploratory Study Using Self-Regulated Self-Development \(SRSD\) and Technology in the Context of the Classroom](#)
- [School Management Software in a Primary School in Victoria, Use of](#)

PRINCE2

- [Value of Teaching PRINCE2 Project Management Methodology](#)

Principles

- [Digital Citizenship, A Sociocultural Snapshot](#)

Prior Programming Experience of Undergraduate Computing and Engineering Students in Ireland

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Synonyms

[Computer science education in Ireland; Programming experience of Irish students](#)

Introduction

Historically programming has not been a subject studied at second level in Ireland, and degree programs in Irish third-level institutions have assumed students have no prior experience when approaching the teaching of programming. It has become apparent that increasing numbers of students arriving into undergraduate computing and engineering degree programs in Irish third-level institutions have previous exposure to computer programming, and the situation regarding the teaching of programming in the Irish school system is currently changing. This entry describes the current state of programming experience of Irish undergraduate students on entry to third level, exploring its sources and impact and presenting some comparative international context.

Irish School System

What follows is a brief overview of the structure of the Irish school system in order to provide a context for the following discussion. The Irish school system is made up of primary and second-level education. Primary education consists of an 8-year cycle: junior infants, senior infants, and first to sixth classes. Pupils normally transfer to second-level education at the age of 12. Second-level education begins with a 3-year junior cycle after which students take the Junior Certificate examination. This is followed by a 2-year or 3-year senior cycle depending on whether an optional Transition Year is taken following the Junior Certificate examination. Transition Year is free from formal examinations and allows students to experience a wide range of educational inputs, including work experience. Following their final 2 years in the senior cycle, students take the terminal state exam known as the Leaving Certificate.

Programming Opportunities for Irish School Students

Historically the standard introductory programming course at third level in Ireland assumes no prior knowledge of programming, as it has not been taught as part of a formal subject in the Irish school system. Although a module in

Computer Studies was made available in the 1980s as an optional component of the Mathematics Leaving Certificate subject, it lacked a clear syllabus, and nationally uptake was low. Limited resourcing due to the prevailing economic conditions in the 1980s and early 1990s together with a lack of a clear national policy restricted the ability of schools to develop the teaching of programming.

However, this situation is currently evolving, largely in response to industry demands in the face of a perceived skills gap. This is in line with an international resurgence of Computer Science education in schools. In 2014 an optional short course in Coding was introduced which can be taken during the junior cycle of second-level schooling and Computer Science is being introduced as an optional Leaving Certificate subject in September 2018. Furthermore, the National Council for Curriculum and Assessment (NCCA) is actively considering approaches to introducing the teaching of programming to all students in primary schools through its *Coding in Primary Schools Initiative*. It is clear that third-level institutions will need to adapt to cater for this new generation of students with prior programming experience.

In addition, outside of formal educational settings, recent years have seen a surge of interest in learning to program as evidenced by the phenomenal success of the CoderDojo network of after-school programming clubs. Since its foundation in 2011, the CoderDojo network has grown exponentially to include over 200 clubs across Ireland in January 2017, and the academic community in Ireland has become aware that many students arriving at third level to commence computer science and engineering degree programs already do so with some prior exposure to programming.

Prior Programming Experience of Third-Level Students

Overview

A repeated cross-sectional study using an annual survey of third-level students is currently

underway in Ireland (Strong et al. 2017). It provides empirical data on what programming knowledge and experience students have before commencing undergraduate degree programs with a programming component in Irish third-level institutions and explores how this exposure affects their experience of programming during their freshman year. Data from the 2015/2016 and 2016/2017 academic years of this survey give a view of the Irish student experience and are suggestive of emerging changes. The survey population is freshman students undertaking a third-level, undergraduate degree program in Ireland which involves the studying of programming in first year. Such programs are typically computer science and engineering programs. Students are targeted in the latter part of the second semester of their freshman year, so they can make a judgment with regard to the impact of their prior experience on their current studies.

While the overwhelming majority of the survey population would have undergone their second-level education in Ireland, it should be noted that as of the 2014/2015 academic year, approximately 10% of students in Irish third-level education are “international” students and a number of these students would have experienced some level of formal exposure to programming in their previous education.

From 2016, the survey was circulated to freshman students of eight institutions. The survey collected demographic data such as third-level institution attended, age, gender, and degree program. It then asked if respondents have prior experience. For those that do the remaining questions explored the nature of that experience and its impact on their current study of programming. It should be noted that as students self-assessed their level of confidence and ability, rather than an objective test being applied, this may have introduced some bias, though it is not clear in which direction this may lie.

The early results of this study, while limited in their scope, provide the only indication of the current situation as well as a baseline from which to evaluate the inevitable further changes in the Irish student profile. They are therefore discussed in detail below.

Participants

The sample size for 2016 was $n = 321$ respondents and for 2015 was $n = 122$. Currently in Ireland, female enrolment figures for full-time honors degrees are approximately a mere 15% for computing degrees and 18% for engineering degrees (<http://hea.ie/statistics/>). In the survey there is therefore a slight overrepresentation of female respondents over the 2 years at 25% across the 2 years. Mature students range between 8% (universities) and 20% (institutes of technology) of the student population; the survey participants are generally in line with this.

Programming Experience

Two thirds of Irish students in the survey indicated that they had *no* prior exposure to programming with 34.2% indicating they had some experience prior to the start of their third-level course. These figures are not significantly different from those of the 2015 survey where 63% of freshman students ($n = 120$) indicated they had no prior experience.

Students were also self-reported their prior level of fluency in programming. The 2016 cohort reported having a much stronger level of fluency than the 2015 respondents (see Fig. 1 for figures and an explanation of fluency levels).

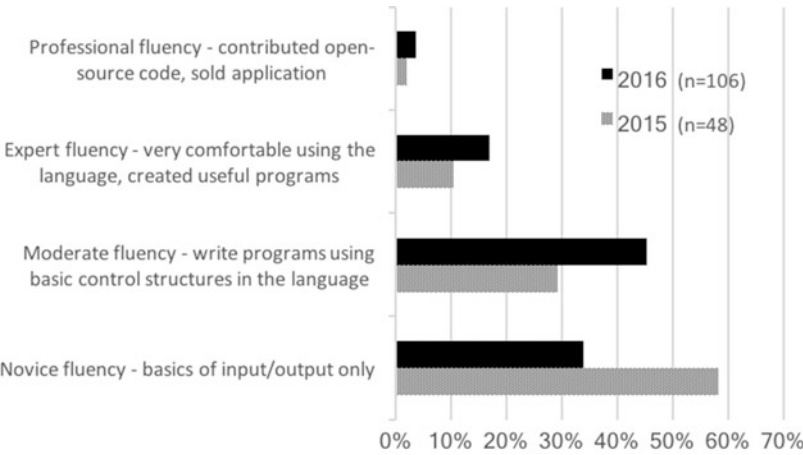
The proportion of Irish students reporting programming experience prior to third level highlights the relatively low level of experience the Irish students have at the outset of their third-level study. This is most likely due to the majority of students coming directly from Irish second-level schools where programming is not yet widely taught. It is notable that the level of fluency reported suggests that for the students who did have experience their previous studies were often deep and considered.

Programming Languages

Students have clearly engaged with a wide variety of languages which is an indicator of the diversity and range of the sources of prior experience. They are outlined in Table 1.

Differences in the survey format between the years are believed to be responsible for the stark difference between the reported exposure to the popular “Scratch” educational language.

Prior Programming Experience of Undergraduate Computing and Engineering Students in Ireland, Fig. 1 Level of fluency from 2015 and 2016



Helpfulness of Experience

10–15% of students reported that their prior experience was not helpful in their freshman year. The responses from the remaining students who did report an impact fell into the following broad categories:

- A head start boosted confidence helping students transition to third level.
- Not struggling with the basic concepts allowed for deeper learning to occur.
- Understanding fundamental concepts helped in adapting to new languages.
- More receptive to understanding complex concepts.
- More time could be spent on studying other modules.

As we might expect, prior exposure to programming concepts is considered helpful when dealing with introductory programming modules. Interestingly, this doesn’t necessarily relate directly to the conceptual knowledge and skills gained from prior experience but instead is on the affective impact of having such knowledge particularly in the area of confidence levels and receptiveness to new learning. This underlines the importance of educators adopting pedagogical approaches that support the growth of confidence in learners. Given the diversity of programming tools and skills encountered, it’s perhaps not surprising that familiarity with the core concepts of

Prior Programming Experience of Undergraduate Computing and Engineering Students in Ireland, Table 1 Programming languages experienced prior to third level

Language	2015 freshmen (n = 48) (%)	2016 (n = 106) (%)
C, C++, C#	33	40
HTML	60	28
Java	44	59
JavaScript	23	17
Other	0	22
PHP	0	12
Python	25	33
Scratch	38	1
Basic variants	4	14

programming had a significant positive impact. Since many introductory programming modules focus on trying to impart these core skills, students who have a head start reported that they can focus purely on advanced constructs or even on other modules.

When students were asked if any specific aspects of their experience were helpful to them, one third indicated that there was nothing specific that was useful.

With the remaining responses, the most frequently cited helpful activities were time spent on projects or practice (19%) and specific online or print resources (15%) notably Codecademy and YouTube.

The fact that a substantial number of students were unwilling (or unable) to identify individual sources of their experience as being helpful could indicate that nothing at all, or no single specific aspect was helpful. However, alternative readings could suggest that they either had difficulty in reflecting on its effect or that their overall experience – rather than specific experiences – was helpful.

Origins of Experience

A particularly interesting question in the Irish context, where programming has not been widely available as a formal school subject and grassroots organizations like CoderDojo report considerable activity, is where students are gaining their experience. Multiple sources for their experience have been reported.

School Activities: 27% indicated that they had participated in programming activities through school. These activities were identified as short summer classes, Transition Year courses (a 1-year program in Irish second-level schools with no formal exams prior to beginning the 2-year terminal examination), elective classes, preparation for programming competitions, and a formal part of school curriculum (international students). The duration of these activities ranged from 1 day to 2 years.

Club Activities: 13% of students reported participation in clubs or groups outside of school. These included CoderDojo and other computer clubs, third-level access and youth programs, as well as adult education courses.

Online Activities: Reported participation in online courses (including courses that they may not have finished) was 42%. The most common sites used were Codecademy, other unspecified tutorial sites, and YouTube and a small number of other specific sites.

Self-Directed Learning: Most students have engaged with any self-directed learning such as books or building projects, with the majority of them designing and developing their own projects, including games, websites, web applications, Arduino/Raspberry Pi projects, and general business applications. The time spent on these

projects varied significantly from a couple of hours to a couple of years with the average amount reported as approximately 40 h.

Other Sources of Experience: 30% of students indicated they had other sources of experience. These included post-second-level school courses that were not diplomas or degrees, previous third-level courses, and previous employment.

When examining the origins of prior experience, it was not unexpected, given the lack of formal inclusion of programming in Irish schools' curricula, that most students had gained their experience outside of school. Indeed, what was surprising was the extent and range of extra courses run by some schools both as part of their day-to-day curriculum and as extra short courses after school.

The low number of students who participated in clubs/groups compared to the proportion participating in school-based activities may seem surprising given the high profile of CoderDojo. However, this may be due to the relative infancy of this club, founded in 2011. This number might be expected to increase in the future in line with the increasing participation and growth of dojos in Ireland. However, it is clear that most non-online computing activities undertaken by students have been via schools.

Not unexpectedly, there is a relatively high number of students undertaking online courses, with Codecademy being the clear leader. The most popular languages being learned online are the web development scripting languages and Python.

Comparative International Perspective

There is a shortage of comparable national studies to place the Irish situation in full context, but some comparisons with international standards can be made. While prior knowledge of programming has generally not been the primary focus of research, some studies have investigated the effects of prior knowledge on such things as confidence levels (Macleod and Patterson 2012), problem-solving (Chen et al. 2007), and

gender balance (Wilson 2002) with previous programming experience often being cited as a predictor of programming success (Madigan et al. 2007; Hagan and Markham 2000). Interestingly, studies have shown that it is not prior knowledge of programming concepts alone but student self-efficacy, or their self-perception of their programming ability that has the strongest correlation with programming performance (Wilson 2001). Krpan et al.'s investigation into the correlation between students' success in introductory programming and mathematical courses included an analysis of student expectations and success rates in introductory programming courses at the Faculty of Science, University of Split, over 3 years. They found that early failure to understand basic programming concepts affects students' confidence and leads to increased drop-out rates (Krpan et al. 2015).

The background of Computer Science freshmen across two Finnish universities was investigated in 2011 and 2012 (Kinnunen et al. 2013). Differing levels of prior programming experience were found between the two institutions (62% and 38%), with the university with the more selective entrance criteria having the higher percentage. It is worth noting that between 43% and 63% of those with experience gained it through formal studies, an opportunity not currently available to most Irish undergraduates.

Data relating to the prior experience of over 900 students at the Eidgenössische Technische Hochschule (ETH) Zurich was collected over 7 years from 2003 and gathered from 77 students from University of York in 2008 (Pedroni et al. 2011). During this time Computer Science was an optional subject not universally available in either Switzerland or the UK at primary or second level, yet in both institutions, prior experience was high, running at a stable level of 78–84% across the 7 years. Interestingly, only 16–25% gained their experience at school, with most reporting self-study as the source.

Conclusion

Currently, roughly a third of freshman students studying computing in Ireland have had some

exposure to programming. To date, a lot of that experience is, necessarily, from self-directed and online study, but a surprising amount stems from schools which emerged as an important driver and facilitator for encouraging students into their first steps in programming. Nonschool clubs such as CoderDojo have grown in numbers and popularity since their foundation in 2011; however their effect in Ireland cannot be seen as yet in the third-level population. Together with the mooted introduction of programming at primary level and the introduction of Computer Science as a Leaving Certificate subject from September 2018, it is clear that the nature and extent of the prior programming experience of incoming undergraduates will be subject to enormous change over the coming decade.

When examining the profile of freshman students in any discipline, there is always diversity in terms of age, background, and general experience. This is a factor that third-level educators have always had to take into consideration when designing courses and choosing appropriate pedagogical approaches. With computer science primary degrees having the highest rate of non-progression in Ireland (varying between universities (15%) and institutes of technology (26%)), it is clearly important that the nature and impact of that previous experience be used as an evidence-base for decisions about future curriculum design and teaching practice, so that introductory courses be made more relevant and appealing to students consequently providing some contribution to student retention and competency levels.

Cross-References

- ▶ [Beginnings of Computing in School Education in Australia](#)
- ▶ [Competency Models in Computing Education](#)
- ▶ [Computational Thinking](#)

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Problem- and Project-Based Learning (PBL)

- [Problem-Based Learning Online](#)

Problem-Based and Project-Oriented Learning (PPL)

- [Problem-Based Learning Online](#)

Problem-Based Learning

- [Modeling of Games and Game Strategies](#)

Problem-Based Learning Online

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Synonyms

[Designs for learning](#); [Didactical designs](#); [Digital methods](#); [Distance learning](#); [Learning design](#); [Netnography](#); [Online learning](#); [Problem- and project-based learning \(PBL\)](#); [Problem-based and project-oriented learning \(PPL\)](#); [Virtual learning](#); [Virtual methodology](#)

Point of Departure

Problem- and project-based learning (PBL) was originally developed for collaboration between physically present students and teachers, but political decisions at many universities also require that collaboration, dialogues, and other PBL activities take place online. Teachers design learning situations with the intention of supporting the students. This study investigates how technology influenced the interaction between teachers and students and between students in two different online modules for master's students at Aalborg University, Denmark. The study aims to answer the research question “How do two online learning designs affect student engagement in the PBL online modules?” The empirical data were collected and analyzed using a netnographic approach. The study finds that concepts such as self-directed learning and active involvement may be perceived very differently from the students' and the teachers' perspective.

This study explores two online modules from two different human computer science education programs at Aalborg University: (1) “Proactive Review – A Design for Organizational Learning” from the Master in Information Technology and Learning (MIL) program and (2) “Development of Competences and Education in a Global

Perspective” from the IT, Learning, and Organizational Change (ILOO) program.

The pedagogical foundation of Aalborg University is the Aalborg Model (<http://www.en.aau.dk/about-aau/aalborg-model-problem-based-learning>), which entails problem-based and project-based learning (PBL). The curriculum of a course frames the problem definition and analysis. The students recognize a dilemma or a forked-road situation and formulate it as a question; this is the problem definition. They comprehend theories from the curriculum to understand the problem, and they utilize relevant methods to gather data. Their analysis is supposed to lead to suggested solutions to the problem (Kolbaek and Nortvig 2018). To stimulate thinking and learning, the students are required to work in groups (Dewey 1916); they complete the course by writing a project report, which is often defended orally in an exam.

PBL is the pedagogical expression of the theory that learning is context based and collaboratively constructed, in opposition to the theory that learning is context independent and individual. PBL requires certain behaviors and responsibilities of the students and the teachers. The students need to be curious (Dewey 1916), capable of identifying relevant research problems, and able to reflect on theories and on their experience from practice (Dewey 1916). They must possess the ability to study in groups and the willingness to take responsibility for running and finalizing projects in due time and with high quality (Tambouris et al. 2014; Kolbaek and Nortvig 2018). According to Tawfik and Lilly (2015), these may be difficult tasks for students who come to the university from other traditions. The Aalborg Model requires certain attitudes and behaviors of the teachers as well. For example, the teachers present fewer lectures and spend more time on supervising group work and scaffolding self-directed learning (Barrows 1996; Hmelo-Silver 2012). The teachers exert less control over the content because the students may define the literature, but the teachers still suggest relevant literature. Thus, the teachers need to be willing to change their role from that of a “boss” to that of a “facilitator” who supervises the students

in all phases of their project work and suggests content related to the course description and the problem formulated by the students (De Graaf and Kolmos 2003; Kolbaek and Nortvig 2018). The teacher leads the final assessment, which is the students’ oral defense of their project or the evaluation of a written report. Therefore, PBL requires students’ engagement independent of the teachers, as well as teachers who both support this independence and support the students in learning the curriculum in order to pass the exam.

This study explores the design *for* and the design *in* learning for two different master’s programs at Aalborg University. The design *for* learning is the learning design that the teacher creates and shares with the students, while the design *in* learning refers to the activities that actually take place when the learning design is in use (i.e., the students’ reactions to the design *for* learning) (Kolbaek and Nortvig 2018; Kress and Selander 2012).

In PBL, the students need to grasp theory according to the curriculum. This study digs into the design *for* and the design *in* learning theory as the foundation for the later project work. Both the design *for* and the design *in* learning are based online (Lajoie et al. 2014). Since the students participating in the study are completing their master’s degree, they possess a bachelor’s degree from various universities or university colleges and are familiar with the processes and responsibilities of PBL from their previous year at Aalborg University. The teachers encourage the students to become involved individually and in groups even though they are geographically dispersed, so the teachers create learning designs that include accessible technology. However, the intention and the response may not be equivalent, and the teachers may realize that the students respond unpredictably to the learning design. Consequently, the design *for* and the design *in* learning may be quite different (Kress and Selander 2012).

This study explores designs *for* learning in two online modules created by the teachers. The designs *in* learning, on the other hand, are the students’ reactions. The designs *for* learning

provide a dilemma: On the one hand, the teachers offer online lessons and scaffolds that are supposed to help the students understand important theories and find relevant resources; on the other hand, the teachers hand over the responsibility for the students' learning to the students.

A Netnographic Case Study

This study is based on online fieldwork in which the students' activities were observed by gathering data from the Internet, mainly from the following sources: Moodle (the learning management system at Aalborg University), Adobe Connect (the university's videoconference system), YouTube, and Google Groups. The study looks into the students' utilization of certain online resources provided by the teachers, as well as online communication between the students and between the teachers and students (Gill et al. 2005). As the collected data and the participant observation research originate in data shared on the Internet, this research practice may be classified as netnography (Kozinets 2015). In this method, the researchers are able to see the same screens and online interactions as the students, but the researchers have access to logged data to which the students do not have access (Jin et al. 2015). In general, netnographers do not know the informants personally but observe them at a "distance" on the Internet. In this case, the researcher was acquainted with the students because they had met face to face in previous lectures. The researcher in this study possesses a double role as a teacher first and as a researcher second. Bias was reduced by using only online data (Kozinets 2015), which prevented the researcher from influencing the students' behavior or feedback through her role as teacher.

The aim of this study is to understand differences between design for learning (the teachers' planning) and design in learning (the students' actions and reactions) when the design is accessible online and requires online participation. Consequently, it seems appropriate to look for traces that the students left behind online to investigate the students' actions and reactions, which

means that learning analytics could be an appropriate approach to this study (Duval and Verbert 2012).

According to Elias (2011, p. 5), learning analytics involves "(1) the development of new processes and tools aimed at improving learning and teaching for individual students and instructors, and (2) the integration of these tools and processes into the practice of teaching and learning." Learning analytics is a relatively new field of research, as "design for learning online" is relatively new compared to "design for learning face-to-face" (Merceron et al. 2016; Schwendimann et al. 2016). The Society of Learning Analytics defined learning analytics as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Siemens and de Baker 2012, p. 252). The data may be gathered from the Internet or from mobile devices.

The point of learning analytics is to retrieve data that the teachers leave behind from designs to look into designs for learning, as well as to retrieve data that the students and teachers leave behind to study design in learning (Duval and Verbert 2012). The intention of learning analytics is to improve education (Siemens and de Baker 2012; Vatrappu et al. 2011). The data may identify differences between design for and design in learning that could support efforts to change the design for learning to improve student success (Elias 2011). Traditionally, data from design for learning stem from teachers' and students' evaluations gathered at the end of the lectures or at the end of the semester; in both cases, the data are self-reported, retrospective, and sometimes quite delayed. By contrast, learning analytics provides data gathered simultaneously with the activities without the interference of a researcher or teacher (Elias 2011).

Empirical Data from Aalborg University, Denmark

This section describes two different programs related to human computer science at Aalborg

University. Both programs consist of 120 ECTS (European Credit Transfer System) that should be completed within 2 years. This study looks into a module of 5 ECTS points from the MIL program and a module of 10 ECTS points from the ILOO program. The designs for learning cover a period of 6 or 7 weeks, during which the teachers present or suggest different themes that the students are supposed to work with (named “student activities”) on different IT platforms. The designs for learning are described in detail for the reader to understand how the teachers planned the students’ engagement in the online PBL modules. The students’ reactions - the design IN learning, is described in the section “Students’ Behavior”.

MIL: A Blended Learning Module

The MIL program is offered by the Faculty of Social Science. MIL requires 20 h of study per week for 2 years. The students must possess a bachelor’s degree and at least 2 years of work experience based on their university degree, including experience with IT development or implementation. MIL students work as professionals in private or public organizations and study part time.

MIL includes the module “Proactive Review – A Design for Organizational Learning,” herein referred to as “Proactive Review.” The aim of this module is to enable the students to learn about organizational learning from theory and practice by grasping organizational learning theories and by experimenting with a design for organizational learning (Kolbaek 2014). This module lasts for 7 weeks, with an accumulated student workload of 137.5 h.

This study looks into the design for and the design in learning for the years 2013 and 2015, during which the students were situated in Denmark and Norway, respectively. The first lecture took place face to face, whereas the rest of the course consisted of only online activities; thus, this module can be classified as “blended learning” (Garrison and Kanuka 2004). The final assessment of the students was based on two elements: participation and a report. The Proactive Review module was planned by one teacher

who was assisted by another teacher during the seminar and the online interactions. Table 1 gives an overview of the design for learning of the module for 2013 and 2015. Both years are included because the number of students was small – only 12 students in 2013 and 17 students in 2015. The design for learning is described in detail in Table 1.

The Proactive Review module started with a face-to-face introduction lasting 4.5 h, in which the students were introduced to theory about organizational learning and the specific design for organizational learning named Proactive Review (Kolbaek 2014). During this introduction, the students were asked to form groups of three to four that they would work with during the course. They were told to decide on the workplace in which to try out at least one Proactive Review. The students had tasks that they had to achieve as a group even though they were geographically dispersed with limited options for meeting face to face. In addition, the students had individual tasks to deliver online.

After the introduction, the students were occupied with other tasks for 5 weeks before they returned to this module. In the meantime, each group of students was supposed to practice at least one Proactive Review in a student’s workplace to get practical experience with this learning design for organizational learning. In week 2, the students had to read the theoretical texts in the curriculum suggested by the teacher, discuss a certain text in their group, and present it for the other groups as a brief text in a discussion forum (i.e., Google Groups in 2013 and Moodle in 2015). These texts served as an introduction to the individual online discussions in week 3, during which the students were obliged to deliver at least two comments on the other groups’ presentations. In week 4, the groups replied to the criticism received in the discussion forum in week 3 and concluded the discussion. At the end of week 4, the students and the teacher met in an Adobe Connect videoconference, and the groups presented their experiment with a Proactive Review and highlighted an obstacle or a problem they had faced. These issues became the starting point for

Problem-Based Learning Online, Table 1 The design for learning for the Proactive Review module

Time	Theme	Students' Activity	IT platform in 2013	IT platform in 2015
Week 1 4 h	Theoretical approach to Proactive Review - a desai for learning in organizations	Listen Roleplays Reflection Feedback Forming groups of 3–4 students	Face-to-face In Class	
Exercise period of x weeks	Practice approach to Proactive Review	Try out a Proactive Review in a students' work place	Face-to-face without teacher at a students' workplace	
Week 2	Theories of organizational learning	Reading and presenting theories	Google groups	Moodle Discussion Forum
Week 3	Theories of organizational learning	Individual reflection and criticizing another theory from the students' basic theory. Minimum 2 comments required	Google groups	Moodle Discussion Forum
Week 4	Theories of organizational learning	Reply to the criticism Conclusion on the discussion	Google Groups	Moodle Discussion Forum
	Proactive Review in practice	Present experience from the Proactive Review including at least one challenge	Adobe Connect video conference 105 min, Challenge described in Google Groups	Adobe Connect video conference. Question asked on in Moodle discussion forum
Week 5	Connecting organizational learning theories and practices of Proactive Review	Discuss the questions raised in the videoconference in week 4 by 3 comments at least	Google groups	Moodle Discussion Forum
Week 6	Connecting organizational learning theories and practices of Proactive Review	Conclude on the discussion and present suggestions for solutions by the end of the week	Google groups	Moodle Discussion Forum
Week 7	Synthesizing	Writing an essay on Proactive Review. 10 pages per group	LMS	LMS

the discussions in weeks 5 and 6, during which each student had to comment on at least two of the problems defined by the other groups. By the end of week 6, the group had to conclude the discussion, and the teacher's intention was for the group to formulate a suggested solution to the problem they had identified. In week 7, the groups were asked to write an essay of ten pages reflecting the learning processes and the results they had achieved from the module. The essays were to be delivered in the learning management system.

ILOO: An Online Module

The ILOO program is offered by the Faculty of Humanity. ILOO requires 37.5 h of study per week for 2 years. The students possess a professional bachelor's degree (e.g., teaching or nursing) or hold a bachelor's degree in the humanities or social sciences. Some of the students work part time. ILOO includes the online module "Development of Competences and Education in a Global Perspective," which lasts for 6 weeks. This includes 24 h of online training in which

the students' participation is optional, but they must pass the exam. During this module, some of the students exchange the lectures for internships in relevant organizations in Denmark or abroad; thus, the lectures are designed for online presence during work hours from 14:15 to 18:15 (CET, Central European Time Zone). The aim of this module is to enable the students to work with learning, training, and IT-related changes, including global perspectives in organizations. Eight teachers share the six 4-hour online lectures. The exam consists of an essay of 10–12 pages per student; if up to 4 students work together, each additional student extends the essay by 2–3 pages (Kolbaek and Nortvig 2018). In 2016, the teachers decided that the essay would be a literature review. To give the reader an overview, Table 2 shows the design for learning of the module “Development of Competences and Education in a Global Perspective” in 2016. These details are necessary to shed light on the huge difference between the students' engagement in the MIL module and in the ILOO module – the design in learning, which is presented in the section “Students' Behavior”.

In 2016, 72 students signed up for the module “Development of Competences and Education in a Global Perspective” which includes six themes that will be described in more detail below. The six themes are divided into the six lectures of the module. The students' activities vary from individual tasks such as individual exercises and listening to the teacher's presentation to online group work. Eight teachers share the six lectures between them. Sometimes three teachers are present during the online sessions, and sometimes only two teachers share the 4-h lectures. No teacher is present during all six lectures. The module utilizes mainly two online platforms: Moodle and Adobe Connect. Moodle provides information about the module, such as schedules, lesson plans, materials to read or watch, links to Adobe Connect videoconference rooms, Google Docs, and links to TED Talks and YouTube video recordings. All the lectures are provided through Adobe Connect videoconferences.

The first lecture is an introduction to the module; the three teachers in charge (BM, DK, and

RB) focus on different concepts of globalization and on the literature review as a genre. Seven teachers participate in all 4 h of this lecture. The students are supposed to prepare for the lecture by reading articles suggested by the teachers in Moodle. Students and teachers meet in a common videoconference room in Adobe Connect. After the introduction to the module, the teacher lectures on different concepts of globalization. At the end of the 4-h session, the students work in groups in Adobe Connect videoconference rooms to identify the topics and issues they want to learn more about during the module. They place their suggestions in a Google Doc. The students are then asked to do an individual literature search, and they place their results in another Google Doc. Finally, the teachers wrap up and close the session. Based on the schedule of the session, the teachers should speak for 195 min, and the students should do something other than listening for 45 min (breaks are not included).

The second lecture covers inclusion as a topic and is run by three teachers (AT, BM, and EK). As preparation for the lecture, the students are supposed to watch two videos (lasting 3.39 min and 22 min) and read two articles about the topic. After the teacher's introduction, the students are invited to reflect upon the term “globalization” as a continuation of the lecture from the week before. This is an individual task; the students write their reflections in a discussion forum in Moodle. A teacher lectures about inclusion and exclusion from a global perspective; this is followed by a discussion between the students in groups in videoconference rooms and the groups' presentations of their views in the common videoconference. Next, another teacher lectures on inclusion in Danish schools; at the end of the lecture, the students are invited to discuss this topic in a videoconference. According to the plan, the teachers are supposed to lecture for 95 min, and the students are supposed to participate in something other than listening for 145 min (breaks not included).

The third lecture is on culture and intercultural communication. As preparation for the lecture, the students are supposed to read three articles suggested by the teachers (BM, DK, and HH);

Problem-Based Learning Online, Table 2 Design for learning in the ILOO module “Development of Competences and Education in a Global Perspective”

Time	Theme	Students' Activity	Teachers	IT platforms
Week 1	Introduction to Concepts of globalization Literature review as a genre	Listen to teacher's presentation in videoconference Group discussions in Adobe Connect group rooms, to identify topics and issues they wanted to know more about during the module stated in a google doc Individual literature search Teachers' wrap up	BM DK RB	Videconferencein Adobe Connect Moodle Google docs
Week 2	Inclusion	Watch two videos before the lecture Listen to teacher's introductions Adobe Connect videoconference Individual student reflections on “giobaizatson” placed in Moodle Teacher presentation of inclusion and exclusion in a global perspective Group discussion in the video conference Teacher presentation of Inclusion in Danish schools Discussion in the video conference Teachers' wrap up	AT BM EK	Ted Talk. You Tube Videoconference in Adobe Connect Moodle
Week 3	Culture and Intercultural Communication	Listen to teacher's introductions videoconference Watching teacher's presentation on video Group work in Adobe Connect group rooms, and presentation of the restila in Moodle Listen to the teachers' conclusions on the groups work presentations Watching teacher's presentation on video Individual or group exercise, students' choice Exempts. the theory, and ask questions to at least two of the fellow-students' examples Wrap up Student feedback in Moodle discussion form	DK HH	Videconference in Adobe Connect Adobe Connect group rooms Moodle Video-presentation in YouTube
Week 4	IT and the understanding of technology in global education	Listen to teacher's introduction in videoconference Group work, each student finds a text and present this text for the fellow students in the group, and the group identifies challenges in online learning design Teachers' conclusion and wrap up on group work Group work on design <i>for</i> learning for geographical dispersed students. Specific focus on the choice and impact of the technology. Links in Google doc Group work in which the design <i>for</i> learning is tested on another group, feedback in a google doc Discussion and conclusion in plenum	AN CW	Videconferencein Adobe Connect Adobe Connect group rooms Moodle Google doc
Week 5	Citizenship and field work in Online setting	Listen to teacher's introduction in videoconference Watch the teacher's 13 min video-presentation about citizenship Group discussion in about citizenship, and	AN BM	Videconference in Adobe Connect Adobe Connect group rooms Moodle

(continued)

Problem-Based Learning Online, Table 2 (continued)

Time	Theme	Students' Activity	Teachers	IT platforms
		formulate two questions to be discussed by other groups. Place the questions in Moodle. Individual reflection and commenting on other groups' questions Watch video teacher's presentation about netnography 19 min Individual contributions to a blog (discussion forum in Moodle) by taking a specific religious or political approach . . . and discuss citizenship from this perspective When answering other's contributions change role to "researcher". Listening to teachers' wrap up		Video-presentation in YouTube
Week 6	Participatory Culture and Makerspace	Discuss the homework on Makerspaces Watch the teacher's 20 min video presentation about Makerspaces Group work, exemplify the theory on a specific makerspace and prepare a presentation for fellow students Individual evaluation of the module in a Google doc The groups present their exemplifications for half of the students in an Adobe Group room Watch teacher's 14 min video about literature review Exercise on literature review, suggestions in a Google doc	HH DK	Videoconference in Adobe Connect Adobe Connect group rooms Moodle Video-presentation in YouTube Google docs

Source: Moodle, ILOO9, 2016

the students can watch two videos that cover two of the texts if they prefer Danish spoken videos over English written texts. After the teacher's introduction, the students are given time to watch the first 14-min video produced by one of the teachers. The video is followed by two exercises in which the groups exemplify the theory; half of the students work on one exercise, while the other half work on the other exercise. The groups collaborate in Adobe Connect videoconference rooms and present their results in a discussion forum in Moodle. The teacher comments on their results. The students are then asked to watch a teacher-produced video on an alternative conception of culture. The video lasts for 15 min and is followed by three exercises that the students do individually. The students put the answers in a Moodle discussion forum, and the teacher comments on their contributions before she wraps up and encourages the students to write their feedback on the lecture in Moodle. According to the

plan, the teacher should lecture for 90 min (including the two videos), and the students should be active in tasks other than listening/watching for 150 min.

The fourth lecture, presented by two teachers (AN and CW), is on IT and the understanding of technology in global education. As preparation for the lecture, the students are supposed to read two articles and prepare a 5-min presentation on a relevant article. The students try out the website www.learningdesigner.org to plan an online lecture. After the teachers' introduction, the students are divided into groups that meet in Adobe Connect videoconference rooms, where they present the article to fellow students. The group identifies challenges in online learning design according to the presentations. Everybody meets in the common videoconference, where the teachers conclude the exercise before the students go back to their groups to create a learning design for online teaching that addresses the challenge they

identified in the first exercise. Later, every group tries out their design on another group and receives feedback. Finally, the students share their reflections on this lecture in the common videoconference. According to the schedule, the teachers are supposed to talk for 95 min, whereas the students are supposed to interact with each other for 145 min.

The fifth lecture addresses the topic of citizenship and fieldwork in online settings and is presented by two teachers (AN and BM). The students are supposed to prepare for this lecture by watching a 10-min video accessible via the university library and by reading two articles. After a brief introduction in the common videoconference, the students are asked to watch a 13-min video produced by one of the teachers before they meet in groups in Adobe Connect videoconference rooms. The groups discuss the term “citizenship” and formulate two questions, which they place in a Moodle discussion forum. Individually, the students read, choose, and reply to two questions asked by another group. The subject then changes to netnography, and the students are asked to watch a 19-min teacher-produced video. Next, the students are asked to contribute to a blog (discussion forum in Moodle). Finally, the teacher concludes the videoconference before wrapping up. According to the plan, the teachers are supposed to talk for 105 min, whereas the students are supposed to do something other than listening to the teacher for 120 min.

The sixth and final lecture in this module includes the topics of participatory culture and makerspace, which are presented by two teachers (DK and HH). As preparation for this lecture, the students are supposed to watch a 20-min teacher-produced video about makerspaces; they then reply to two questions asked at the end of the video and place the answers in a Google Doc. The students are also asked to read three articles. The Google Doc serves as a way for the students to brainstorm on their understanding of and approach to makerspaces, which they discuss from the beginning of the lecture in the common videoconference. The students are then asked to watch another 22-min teacher-produced video on

makerspaces. The students and teachers meet again in the common videoconference, and the students are divided into groups that apply the theory to different makerspaces and prepare a presentation. As this is the final lecture in the module, the students are invited to give thorough feedback in a Google Doc on an individual and anonymous basis. The next activity is the students’ presentations. The students are split into two groups that go to two Adobe Connect videoconference rooms with a teacher who facilitates the session. The students then return to an individual activity, namely, watching a 14-min teacher-produced video presentation on literature reviews. They then suggest “search words” for a literature review and place them in a Google Doc. According to the plan, the students should listen to the teachers for 55 min and do other activities for 185 min.

Students’ Behavior

This section explores the students’ reactions to the design for learning being the design in learning. More specifically, the analysis looks into how the two learning designs affected student engagement in the modules. MIL had only 2 teachers, 12 assigned students in 2013, and 17 assigned students in 2015, whereas ILOO had 8 teachers and 72 assigned students in 2016. The expected workload for the students was 20 h a week for the MIL students and 37.5 h a week for the ILOO students. The MIL students met face to face for 4 h in the introduction, while the ILOO students met only online during the module. MIL included only one theme, namely, Proactive Review, while ILOO included six different themes. Table 11 in Appendix A shows the students’ activities week by week according to the data gathered from the online sources. Data from Table 11 are presented below by theme.

Preparation: Heroes and Villains

This section looks into the students’ preparation for attending the online classes (Table 3).

To gain experience with a design for organizational learning, 100% of the MIL students in both

Problem-Based Learning Online, Table 3 MIL students' preparation

MIL students' preparation for the module "Proactive Review"					
	Student activities	2013	Degree of participation in 2013	2015	Degree of participation in 2015
Week 1	Number of students attending the introduction	12	100%	17	100%
Week 1	Number of groups	4		7	
Week 2	Number of PR's in a student's workplace	4	100%	7	100%
Week 2	Number of presented theories	4	100%	7	100%

Source: Table 11, Appendix

Problem-Based Learning Online, Table 4 The ILOO students' preparation

ILOO Students' Preparation for the module "Global Perspectives on Competence and Educational Development"						
72 students signed up for the module						
Week	1	2	3	4	5	6
Watching video before participation in the online class	NA	NA	0 Clicks	NA	NA	22clicks/ 32% viewed
#students/ percentage of students						
Watching videos #views Average percentage viewed	NA	2 videos Statistics not available	61 clicks. 68% viewed 53 clicks 60% viewed	NA	32 clicks/ 39% viewed 29 clicks/ 53% viewed	32 clicks/ 62% viewed

Source: Table 11, Appendix

NA means "not applicable," as no data is available

years prepared and practiced a Proactive Review in a student's workplace and identified the challenges involved. They had to engage and make it happen without further teacher support; since they were geographically dispersed, they prepared online on IT platforms of their choice. The MIL students also had to read texts as preparation for their group work. The data show that all the students in both years presented the theories as required (Table 3).

To understand the theme of the day, the ILOO students were supposed to read texts and/or watch video presentations before attending the lectures in Adobe Connect videoconferences. The data do not show the extent to which the students actually read the texts, but the log uncovers that the first video in week 3 had 61 clicks, and in average the video was watched 68%. The second video in

week 3 had only 53 clicks and was viewed 60% in average. The first video in week 5 had only 32 clicks, and in average these clicks made the watchers view only 39% of the video. In week 6 the video was clicked upon 32 times, and in average it was watched 62%. The few clicks and the small portion of videos viewed show that the students hardly watched the video presentations (Table 4).

The teachers had handed over the responsibility for learning to the students, and the MIL students embraced this responsibility both for reading texts and for practicing a design for organizational learning in "real life." By contrast, the ILOO students did not take responsibility for watching the videos in full; unfortunately the data do not show the extent to which they read the texts.

Videoconferences: Lusting or Lurking, Listening, and Leaving

The lectures were placed in Adobe Connect videoconferences to ensure accessibility for all students despite their geographical distance to the university and to fellow students (Table 5).

The MIL students only participated in a single videoconference lasting for 105 min. All students participated from beginning to end (in both years), presenting and discussing their experience with the design for organizational learning. It seems as if the MIL students “lusted” to collaborate in the videoconference (Table 5).

Only 59% of the ILOO students participated in the first of six videoconferences; this number declined over the 6 weeks to 31%. With each 4-h online lecture, student participation declined, becoming worse over the 6 weeks. In the first week, 50 students attended the introduction, but only 21 students (42%) participated in the wrap up. In the second week, 41 students (51%) attended the introduction, but only 18 students made it to the wrap up. In the third week, 40 students (56%) followed the start of the lecture, but only 11 students completed it. In the fourth week, 22 students (31%) connected to the videoconference, but the data do not show how many stayed up to the end. In the fifth week, 26 students

(36%) attended the introduction, but only 7 students made it to the end. In the sixth week, 22 students (31%) participated in the introduction, and 9 students kept on until the wrap up. The ILOO students seemed to mainly lurk in the videoconferences with very poor engagement, so they missed the opportunity to learn from the teacher or to collaborate with fellow students (Wilkerson 2016). The students were familiar with the technology and with each other from previous semesters, so a lack of technological knowledge or unfamiliarity with the other participants could not be the reasons for not showing up or leaving early (Table 6).

Online Group Work: Barking Up the Wrong (or Right) Tree

PBL is founded on group work; thus, group work is an integrated part of the design for learning in both MIL and ILOO. The group work is supposed to enhance engagement, learning, and reflection (Dewey 1910; Kolmos et al. 2004) (Table 7).

In both years, all MIL students attended the group work. In the first year, the 12 students decided to form 3 groups instead of 4 because they wanted to engage with more fellow students in the group work. The MIL students worked in groups according to the schedule and IT platforms

Problem-Based Learning Online, Table 5 MIL students’ participation in video conference

MIL students’ participation in video conference					
	Student activities	2013	Degree of participation in 2013	2015	Degree of participation in 2015
Week 4	Presentation of experience with Proactive Review including a challenge in Adobe Connect video conference	3	100%, the number of groups declined to 3	7	100%

Source: Table 11, Appendix

Problem-Based Learning Online, Table 6 ILOO students’ participation in video conferences

ILOO Students’ participation in video conferences						
72 students signed up for the module						
Week	1	2	3	4	5	6
Participation in the introduction to the theme #students/ percentage of students	50/59%	41/57%	40 56%	22/31%	26/36%	22/31%

Source: Table 11, Appendix

Problem-Based Learning Online, Table 7 The MIL students' engagement in online group work

MIL students' engagement in online group work					
	Student activities	2013	Degree of participation in 2013	2015	Degree of participation in 2015
Week 1	Number of groups	4		7	
Week 2	Number of PR's in a student's workplace	4	100%	7	100%
Week 2	Number of presented theories	4	100%	7	100%
Week 4	Reply and conclude on theoretical discussion	4	100%	7	100%
Week 4	Presentation of experience with Proactive Review including a challenge in Adobe Connect video conference	3	100%, the number of groups declined to 3	7	100%
Week 6	Conclude and describe suggestions for solutions	3	100%	7	100%

Source: Table 11, Appendix

they had decided on, and the teacher was only involved occasionally. These groups decided on the workplace in which the design for organizational learning should be tested. They tested and reflected upon the experience in the groups, and the groups presented their experience in a video-conference. The groups also presented a relevant theory in a discussion forum in Moodle, which other students criticized. The MIL students engaged in the group work independently of the teacher, as the group members met online to solve the tasks required in the module. The students interacted with the teacher when convenient, when they wanted to clarify the requirements, or when they were in doubt. We may say that the teacher “delivered on demand.” (Table 7).

The teachers had prepared 11 groups for the ILOO students, but the first lecture included 10 groups due to the declining number of attending students. The number of participating students varied over the weeks; the number of groups declined to three in week 2, increased to five in week 3, disappeared in week 4, increased to six in week 5, and decreased to five in week 6. Looking into student engagement within the group work, it appears that out of the ten groups, only eight groups contributed to the Google Doc in week 1. In week 2, only eight students delivered nine comments in the Google Doc; the data indicate that the comments were written on an individual basis. In week 3, all five groups presented their group work in a Moodle discussion forum, but in week 4, no students engaged in

group work, and only one comment was delivered by a single student. In week 5, the 6 groups were supposed to deliver 12 questions to be answered by other groups, but the 6 groups only delivered 7 questions. In week 6, only three groups out of five presented an example of a makerspace. The students were supposed to do the group work throughout the online lectures, and the teachers were available for questions or comments. But the students did not utilize the teachers even though they were accessible, which may indicate that the students engaged only briefly in the module. Although the teachers were present throughout the online group work, the students did not interact with them and did not take the opportunity to get help to achieve the requirements. The design for learning at ILOO included online group work during the online class and excluded group work between classes. We may say that the teachers “delivered on time” in opposition to the design for learning at MIL that excluded online group work during the video conference and included online group work before and after classes. The fact that the ILOO students engaged only briefly indicates a lack of interest despite the teachers' efforts to make an engaging design for learning. Perhaps the ILOO students were trying to reveal that the teachers were barking up the wrong tree. The lack of engagement and the lack of feedback gave the clue “something must be changed,” but did not indicate what “something” should be (Table 8).

Individual Contributions: Why Bother?

The students were asked to reflect upon theories and personal experience to enhance their learning (Table 9).

The MIL students engaged in individual contributions in weeks 3 and 5. They engaged in the discussion in both years by delivering more comments on average than required, as indicated by the 150% and 154% participation rates in 2013 and 2015, respectively (Table 9).

The ILOO students’ level of engagement in individual contributions varied over the 6 weeks. In the first week, no data was available. The percentage of attending students who contributed individually to the discussion forum as required was 22% in week 2, 20% in week 3, 77% in week 4, 38% in week 5, and 50% in week 6. The ILOO students did not seem to feel obliged to contribute their reflections to the collaboration in the discussion forums, which prevented them from learning by putting their experiences, concerns, or doubts

into words. This hindered them from learning from each other (Table 10).

Video Presentation: Snooping and Sneaking

The video presentations of content should make it easier for the students to grasp theories or understand terms. Some of the video presentations were produced by TED Talks or other professional providers, while others were produced by the teachers. The videos were available before, during, and after the lectures. The MIL students had no video presentations in the curriculum.

The ILOO students were expected to watch eight videos over the 6 weeks. In weeks 3, 5, and 6, the design for learning allotted time for watching the videos during the lectures, but most of the students ignored this resource, and very few students watched a video from beginning to end (Table 5). The statistics indicate that the videos were mainly watched during the lectures, and no videos were watched all the way through after the

Problem-Based Learning Online, Table 8 The ILOO students’ engagement in online group work

ILOO Students’ engagement in online group work						
Week	1	2	3	4	5	6
Participation in the Croup work # groups/ Percentage of participation Expected contributions	10/91% 8/73%	8 students divided into 3 groups delivered 9 comments	5 groups/ 100% of the only 40 attending students	9students/ 13% 1 comment	6 groups/ 100% 7 questions/ 58%	19 students in 5 groups 86% of the 22 attending students 3 groups presented 60%

Source: Table 11, Appendix

Problem-Based Learning Online, Table 9 The MIL students’ individual contributions

MIL students’ individual contributions					
	Student activities	2013	Degree of participation in 2013	2015	Degree of participation in 2015
Week 3	Each student delivered at least 2 comments on other theories presented by other groups Average comments per student	29 2,4	131%	36 2,1	105%
Week 5	Discuss the challenges raised in the videoconference in week 4 by at least 3 comments per student				
	Number of Students’ comments	54		79	
	The average number of comments per student	4,5	150%	4,6	154%
	Number of teacher comments interventions	21	28% of the comments	14	15% of the comments

Source: Table 11, Appendix

Problem-Based Learning Online, Table 10 The ILOO students’ individual contributions

ILOO Students’ individual contributions						
Week	I	2	3	4	5	6
Individual contributions to discussion forums #students/ percentage of expected contributions	N A	9/22%	8students 20% of the present students	17 students/ 77% of the present students	10 students/ 38% of the present students	11 students/ 50% of the present students

Source: Table 11, Appendix

lecture. Students who did not attend the lectures did not watch the videos either. The first video in week 3 had 61 clicks, which suggests that 85% of the students had accessed the video. But the teachers also took the opportunity to watch the video, and an average of only 68% of the video was watched; this means that although a number of people saw the video all the way through, a substantial number only watched portions of it. The second video in week 3 had 53 clicks, and only 60% of it was viewed, so very few viewers saw all of it. In week 5, the first video had 31 views, which is more than one click per attending student. On average, 39% of the video was watched, so only a few minutes were shown to the 31 viewers. The second video had 29 clicks, which is more than one click per attending student. However, only bits and pieces were watched, as an average of just 53% of the video was viewed. In week 6, the students were supposed to watch the video as preparation for the lecture. Twenty-two students attended this lecture, and the video had 22 clicks, but an average of only 32% of it was viewed. This means that some students just clicked on the video and watched no more than a few minutes. The design for learning allowed the students to watch the second video during the lecture; the video got 32 clicks, and an average of 62% of it was viewed. Some students may have watched most of or even the full video.

Conclusion

This entry explored the research question “How do two online learning designs affect student engagement in the PBL online modules?” The analysis raises the question of why students in

one program engage intensively in the module while students in another program hardly engage in the module at all. The latter caused frustration among the teachers, who looked for explanations in order to change the design for learning and engage the students in the future.

Did the technology affect student engagement negatively? The MIL students experimented with Google Groups in 2013, and the “new” technology did not seem to scare them away. In 2015, the MIL students utilized Moodle, which they knew from the previous semester. The technology did not seem to affect MIL student engagement negatively. The ILOO students were familiar with Moodle from previous semesters, but the videoconference was new to them. Utterances in the video recordings make it clear that the students found it hard to switch between Moodle and the videoconference and hard to access the group videoconference rooms. This may be a reason for dropping out (Amichai-Hamburger et al. 2016). Another reason may be that the technology makes it easy to access the lecture and seemingly be present even though the student has left the room or is mentally absent—they can sneak out without getting disapproving looks from the teacher.

The duration of the videoconferences may affect student engagement (Ravitz and Blazeovski 2014). The MIL students met only once in a videoconference for 105 min, while the ILOO students met every week for 240 min. The MIL students were engaged from the beginning to the end of the videoconference, but only a few of the ILOO students stayed for the 4-h lecture – if they showed up at all. A 4-h videoconference seems to be too long even if the students are invited to interact with each other in smaller groups or individually in

discussion forums for half the time (in weeks 1 and 3) or more than half the time (in weeks 4–6).

The formal requirements may also affect student engagement. The required student competences differed between the programs. The MIL students had already worked full time for at least 2 years, they studied part time while working in full-time jobs, and they were more than 30 years old. The ILOO students were young, full-time students. The MIL students needed to be highly motivated to take up this huge extra task of studying, whereas the ILOO students did not study as an extra task but as their “full-time work”; perhaps their motivation was not so clear to them. The requirements of participation also differed. The MIL students could pass the exam by participating in the activities and writing a short essay, or they could deliver a bigger report if they did not engage in the training. The ILOO students participated in the online lectures on a “voluntary” basis, as these lectures could be perceived as resources the students could choose when convenient. In the end, they had to deliver a literature review independently of their participation in the lectures. These different requirements for the two modules may have had a positive impact on the MIL students’ engagement, whereas the ILOO students could pick and choose, and they chose to engage quite superficially.

Teachers’ involvement is another factor that may affect student engagement. Only two teachers maintained the MIL module, whereas eight teachers were involved in the ILOO module. The two MIL teachers interacted with the students several times a week in the discussion forums. The small number of students enabled the teachers to know each student by name; this fact and the continuous interaction seem to have enhanced the personal relations between teachers and students, which supported student engagement over the 7 weeks. The ILOO students met the teachers only online and just once or twice for 4 h; in between the weekly lectures, they were on their own. The lack of continuity combined with the high number of students prevented the teachers from getting acquainted with the students. The teachers stayed at a distance, and the students never overcame the screen to develop personal ties with the teachers. This lack of personal

relations between teachers and students may have had a negative impact on student engagement.

It is not fair to call the MIL students “heroes” and the ILOO students “villains,” as the preconditions for their studies are so different, but it expresses the teachers’ emotions. The MIL students are older and possibly more self-aware, and they have the opportunity to form personal ties with the teachers, which is more than difficult for the ILOO students. In addition, the ILOO students’ participation did not have an influence on the final requirements of the assessment, whereas the MIL students’ participation was mandatory – unless they preferred to deliver an extended final report.

The teachers’ accessibility may also influence the students’ engagement. The teacher “delivered on demand” for the MIL students, so they interacted with the teacher when they felt the need to during their group work, which took place independently of the teacher’s presence. The teacher “delivered on time” during the ILOO online lectures, and the ILOO students were highly reluctant to interact with the teacher; the data do not provide reasons for this, but perhaps they had snuck out of the online lecture.

PBL requires students’ engagement independently of the teachers, as well as teachers who both support this independence and support the students in learning the curriculum in order to pass the exam. The data showed that teachers’ “delivery on demand” supported the students’ independence to a higher extent than “delivery on time.” Besides, the study shows that the independence enhances the students’ engagement in class and outside class, as the MIL students engaged to a higher extent than the ILOO students.

The students’ engagement affects the result. Only one MIL student dropped out, consequently 90% of the students passed the exam in 2013, and 100% passed the exam in 2015. Only 61 out of the 71 ILOO students signed up for the exam, and 59 ILOO students passed, which is 82% of the ILOO students. Unfortunately the ILOO students did not comment the lack of engagement in any feedback, which the teachers will miss when they change the design for learning to improve student success.

The data identified huge differences between design for and design in learning. The study finds that the teachers and the MIL students seem to share the perception of self-directed learning and active involvement, whereas the teachers and the ILOO students seem to perceive these concepts quite differently.

Appendix A

Table 11 shows the students' activities week by week according to the data gathered from the online sources.

When students went beyond the required contributions, the degree of participation increased to

Problem-Based Learning Online, Table 11a ILOO Students' Engagement in the module "Global Perspectives on Competence and Educational Development" 72 students signed up for the module

	Watching video before participation in the online class #students/ percentage of students	Participation in the introduction to the theme #students/ percentage of students	Participation in the Group work # groups/ Percentage of participation Expected contributions	Individual contributions to discussion forums #students/ percentage of expected contributions	Watching videos #views Average percentage viewed	Participation in the wrap up #students/ percentage of all assigned students/ percentage of participating students	Number of minutes utilized for other activities than listening to the teachers
Source 5	YouTube	Adobe Connect Moodle	Moodle Goode Doc Adobe Connect	Moodle Google Doc	YouTube Ted Talk	Adobe Connect	Adobe Connect
Week 1	NA	50/59%	10/91% 8/73%	N A	N A	21/29%/42%	120 min
Week 2	NA	41/57%	8 student, divided into 3 groups delivered 9 comments	9/22%	2 videos Statistics not available	18/25%/44%	80 min
Week 3	0 clicks	40/56%	5 groups/ 100% of the only 40 attending students	8students/20% of the present students	61 clicks/ 63% viewed 53 clicks/60% viewed	11/15%/27%	120 min
Week4	N A	22/31%	9students/ 13% 1 comment	17 students/ 77% of the present students	N A	No data	175 min
Week 5	NA	26/36%	6 groups/ 100% 7 questions/ 58%	10 students/ 38% of the present students	32 clicks/ 39% viewed 29 clicks 53% viewed	7/9%/ 27%	200 min
Week 6	22 clicks viewed 32%	22/31%	19 students in 5 groups/86% of the 22 attending students 3 groups presented	11 students/ 50% of the present students	32 clicks/ 62% viewed	9/41%/13%	180 min

Sources: Moodle, Adobe Connect, YouTube, Google doc

Problem-based Learning Online, Table 11b Overview of the collected data

MIL students' engagement in the module "Proactive Review"					
	Student activities	2013	Degree of participation in 2013	2015	Degree of participation in 2015
Week 1	Number of students attending the introduction	12	100%	17	100%
Week 1	Number of groups	4		7	
Week 2	Number of PR's in a student's workplace	4	100%	7	100%
Week 2	Number of presented theories	4	100%	7	100%
Week 3	Each student delivered at least 2 comments on other theories presented by other groups Average comments per student	29 2,4	131%	36 2,1	105%
Week 4	Reply and conclude on theoretical discussion	4	100%	7	100%
Week 4	Presentation of experience with Proactive Review including a challenge in Adobe Connect video conference	3	100%, the number of groups declined to 3	7	100%
Week 5	Discuss the challenges raised in the videoconference in week 4 by at least 3 comments per student				
	Number of students' comments	54		79	
	The average number of comments per student	4,5	150%	4,6	154%
	Number of teacher comments/interventions	21	28% of the comments	14	– 15% of the comments
Week 6	Conclude and describe suggestions for solutions	3	100%	7	100%
Week 7	% of students that passed the exam	91%		100%	

Data sources: First class, Google groups, Moodle, Adobe Connect

more than 100%. For example, in week 3, the students were supposed to deliver two comments in the discussion forum, but they delivered an average of 2–4 comments; thus, the participation increased to 131%.

61 ILOO students signed up for the exam, and 59 ILOO students passed, i.e., 82% of the ILOO students.

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Problem-Based Learning Putational Thinking

► Modeling of Games and Game Strategies

Problem-Solving

► Computing Education, Outcomes of

Problem-Solving in Computer Science, Learning from a Gifted Peer

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Introduction

How does the problem-solving process of high performers differ from that of low performers and what are the different strategies used in the work phase? These questions were examined at the beginning of the video project in a *think-aloud* study. For this comparative study, two groups of eight participants each were asked to solve typical problems of computer science (CS) in individual sessions and to verbalize their thoughts aloud. The first group, which will be referred to as the group of high performers in the following, was composed of the winners of the annual national competitions in computer science of 2 years. The participants were between 17 and 19 years old. For all of the eight participants, an IQ higher than 130 was determined, which is considered as the threshold to psychometric intellectual giftedness (Waldmann and Weinert 1990). The participants of the contrast group, which will be referred to as the group of low performers in the following, were recruited from students studying CS at the University of Potsdam. They were aged 22–30 years, showed predominantly medium to low academic performance in subjects with a theoretical-formal focus, and described themselves as weak problem-solvers in a survey.

The verbalizations as well as the sketches produced by the test persons while solving the task were recorded by video camera. Subsequently the data were evaluated using qualitative content

analysis as described by Mayring (2014). A detailed description of the test procedure and the evaluation method can be found in Kujath (2006, 2007). Based on the results of a graph coloring problem used in the study, fundamental differences of high and low performers' approaches in problem-solving will be discussed in part A of this paper. The graph coloring problem is outlined in Kujath (2008) including an extensive discussion of the solution.

Considering the significantly different approaches in the two comparison groups and the noticeably higher success rate among the high performers, the next logical step was to identify the more efficient problem-solving methods in order to impart them to the weak problem-solvers with the help of didactic concepts. As for the question of teaching aid, the form of an educational video was chosen since it gained support in the educational community recently not least because of its easy distribution possibilities over the Internet. Despite the known weaknesses of the medium due to its one-dimensionality, the educational video offers an added didactic value through high vividness and the possibility to present complex procedures dynamically (Kittelberger and Freisleben 1994). Paivio (1986) and Berk (2009) see benefits of this audiovisual medium from the perspective of the psychology of learning as well, as contents of instruction can simultaneously be presented in different forms of presentation (picture vs. text), which increases the attention and learning performance. An educational video can offer an even greater learning effect, if it is not used in isolation, but in the context of a suitable teaching concept (Sailer and Figas 2015), e.g., as an introductory learning tool to a new subject. The resulting educational video shows a fictional high performer working on a comparatively difficult graph coloring problem. The video is available in a German (Kujath 2011a) and an English version (Kujath 2011b). Just as it was done in the study, the high performer speaks out loud his considerations; his continuously created solution sketches on paper are shown in top view and are clarified in sections with animated movie sequences and verbal explanations. The video covers the computational problem-solving techniques "trees" and "recursion," and its content is primarily dedicated to those CS

students who are aware of these methods but are unable to apply them in the context of problem-solving. In part B of this paper, the didactic concept of the video will be outlined, and the filmic implementation of the high performers' strategies will be explained in detail.

Finally, in another comparative study, the learning effectiveness of the final educational video about computational problem-solving strategies was analyzed. We examined whether the didactically prepared findings of the *think-aloud* study actually evoke a learning effect for weak problem-solvers and, if so, to what extent. For this purpose, two separate groups of weak problem-solvers were formed, each consisting of low-skilled first semester CS students of the University of Potsdam. The participants of both groups were asked to solve a graph coloring problem similar to the one shown in the video under the conditions of a written examination: one group after watching the video and the other group without seeing it in advance. The experimental procedure and the results are discussed in part C of this paper.

Results of the *Think-Aloud* Study

The difference between the behavior of high- and low-performing problem-solvers became particularly obvious with a 3-coloring problem (see Appendix). Generally speaking, the problem-solving process of the high performers could be clearly divided into *comprehension* and *analysis* of the problem, followed by the *solution* and its *evaluation* – the phases commonly described in the relevant literature. Already in the first phase, the comprehension of the task, high performers showed notable strengths. Usually, they understood the task completely and correctly already after it was read out by the examiner only once and turned to the task immediately after the starting signal. Consequently, we have no findings about the high performers' techniques of problem and text comprehension due to the lack of verbalizations during this phase. Many of the low-performing problem-solvers started their process by asking the examiner comprehension questions without first looking for an explanation on

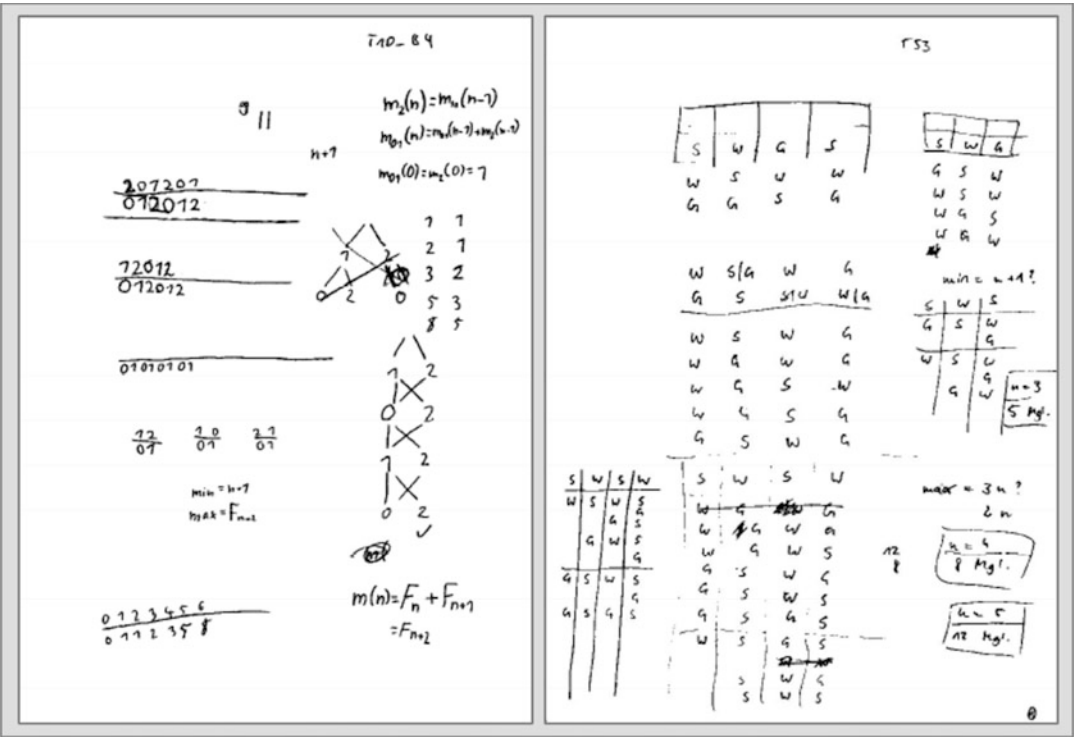
their own. Furthermore, misinterpretations of the task among some of the participants in the group of low performers were not corrected during the entire work process and consequently led to wrong results. Two participants of this group did not understand the task at all.

The first activities shown by the high performers aimed at a detailed analysis of the conditions of the task. In this group, key findings established in this phase were applied exceedingly efficient and purposeful later in the process. This enabled the test persons to construct the answer to the question of the maximum number of color combinations instead of searching for it by unspecific trial of every possible combination. Those key findings were missing to the low performers, who started without exception working on the solution immediately and without a prior problem analysis.

Evident differences were also found in the approaches during the concrete process of problem-solving. Here, low performers were predominantly enactive, trying out all possible color

combinations more or less purposefully, in order to generate generalized statements about the solution from the set of noted color sequences. Even though some solutions were at least partly correct, this approach of problem-solving required intensive writing and was time-consuming as well and thereby also more prone to random mistakes. In the high performers' problem-solving processes, in contrast, distinct fundamental ideas of computer science as described, for example, in Schubert and Schwill (2004) were visible. In the specific context, these were tree structures and recursion, which in combination with the key findings of the analysis phase were purposefully applied.

The perspective on the task was not static, as with the low performers, who considered multiple individual cases, but can be regarded as abstract and dynamic, which is evident in the way they investigated the peculiarities of coloring a rectangle from left to right. As a consequence, the group of high performers mostly showed much shorter and, in addition to that, error-free problem-solving processes. As an example, Fig. 1 shows the original



Problem-Solving in Computer Science, Learning from a Gifted Peer, Fig. 1 Worksheets of participants. Left: participant T10 (high performer group). Right: participant T53 (contrast group)

sketches of two participants, which are typical for the different approaches of the two groups. The left image shows the sole worksheet used by the high-performer T10, clearly indicating the CS methods of tree structures and recursion. The right image shows one out of three worksheets used by participant T53 from the group of low performers. The only apparent strategy here was the creation of complex and ever-growing tables with all possible color combinations.

After the completion of the task, the participants were interrogated about their course of actions and thoughts during their work. All of them were aware of methods specific to computer science like tree structures and recursion in order to solve problems. However, most of the subjects from the low-performer group did not even consider using any of them. Two subjects from that group expressed thoughts like “I shortly thought of it, but then dismissed the idea.” They claimed that the fundamental ideas of CS had been imparted to them merely in theory and without any problem-related examples. Furthermore, many of the low performers tried to avoid dealing with CS tasks as much as possible or gave up very early in the process. This was obvious due to expressions in the interviews like “I know I usually don’t find the right answer, so I don’t even start trying.” The following table outlines the differences between the approaches of the high and low performers, which have been identified through the verbal protocols (Table 1).

Concept of an Instructional Video for Teaching Informatic Problem-Solving Strategies of High Performers

Motivation

Many weak problem-solvers avoid the confrontation with CS problems because of the reasons stated above resulting in tedious working time and the anticipated failure. However, working on such problems is indeed what creates a deeper understanding of the matter and leads to a growing fundus of schemata on how to solve problems which results in the ability to explore even more complex contexts (Fuchs 2006; Friege 2001). The didactic and multimedia preparation of the study’s

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 1 Different phenomena of the participants during the work process

High performer	Low performer
Quick comprehension of the problem	Often immediate questions to the examiner
Intensive analysis of the problem ⇒ focused use of key findings	No analysis of the problem ⇒ key findings either found by chance or disregarded
Clear division into subproblems	Rare division into subproblems
High level of abstraction, concretion as needed	Enactive approach, only concrete data
Strong idea about the fundamental ideas of computer science	Unspecific approaches through trial and error
Question: What happens at the transition from n to $n + 1$?	Question: How many possibilities are there with $n = 1, 2, 3$, etc.

findings is intended to close the obvious gap between teaching of declarative contents in the lectures, where the fundamental ideas are mostly presented without any concrete examples, and training of procedural skills. It is intended to help learners discover how to use the principles of the fundamental ideas of computer science to solve problem-related contexts. With the help of an audiovisual representation of the high-skilled problem-solvers’ approaches – that is, by teaching the “tricks of high performers” with a video – the learner without practical experience is supposed to see how the theory of the lecture can be put into practice. The strategies of the high performers shown in the video point out typical beginners’ mistakes and their problems, such as deficient comprehension of the problem, subject-unrelated approaches, or the trial-and-error method. Learners are supposed to achieve a general ability to use common CS specific problem-solving techniques to effectively deal with exemplary tasks.

Justification for the Choice of Using the Medium “Film”

There is a variety of views on the medium “instructional video” in literature. Kittelberger and Freisleben (1994), for example, refer to the comparatively high familiarity of the medium “film.” However, this entails the danger of watching the movie or a short clip rather as an

entertaining medium and missing the educational message behind it. Lippert (1987), on the other hand, sees a big advantage in the medium “film,” since the audience is more likely to decode the message of the movie due to a higher amount of experience in film-visual perception. Another point of criticism is the linearity of a movie and the lack of feedback and alternative sequences. On the other hand, movies have a high density of information as well as a high vividness through visualizations and dynamic picture sequences (higher perceptive input). This leads to the possibility to teach even complex contexts with just a few means of expression, which otherwise can be difficult to be explained and less vivid. Image, sound, and sequences of actions address more perceptual categories, which leads to an additional didactic value of the medium “film” (Kittelberger and Freisleben 1994). Additionally, Paivio (1971) reports an increase of the viewer’s memorizing performance of learned material, if relevant points are presented with verbal as well as visual information. If used appropriately, a movie creates a realistic environment, which increases the amount of involvement and the possibility of identification and thereby also increases the learning effect of the viewers.

The cinematic presentation of results from an *Aloud* session is outlined in Heller et al. (1993). Projects in the USA are portrayed, in which the original tapes of the sessions with highflyers or experts are shown to low performers. In some sessions, the high performers worked live and *aloud* in front of a group of low performers. However, from the authors’ point of view, this approach seems problematic. Firstly, experience shows that the verbalizations are hard to understand at times. The voice of the participants is often too quiet, the formulations sometimes just consist of small clauses, or the whole thinking process is discarded by the problem-solver. Secondly, due to missing clarifications, the observer is left alone with the entire process. Consequently, the concept presented here follows an alternative approach. First of all, the verbalizations of the participants were linguistically smoothed. Afterward, strategies and typical elements commonly used by the high performers were chosen. Finally,

everything was put together into an optimized problem-solving process. The high performers’ sketches were processed in a similar way. The resulting edited process was acted out in the style of a *think-aloud* session by a professional actor in proper voice and audio quality. The individual activities were contrasted with animated comments in the fashion of an instructional video. The aim is to enable the viewer to reach a complete understanding and a continuous comprehension of the presented problem-solving steps. Educational experts recently discussed a further advantage of educational videos. Thanks to the possibility of the dissemination via the Internet, they can contribute to time and location independent learning and facilitate to review the material again later at home. Consequently, the medium “film” offers an additional possibility of visualization and represents an appropriate and valuable course material. However, the authors argue that the medium should not be used isolated but always as an additional tool in an educational framework.

Concept Description

Definition of the Target Groups

The intended audience of the video are those students of computer science who are aware of the theoretical concepts like tree structures and recursion, but lack the corresponding procedural abilities and experiences to use these instruments. This concerns students who recently learned these structures as well as those students who have been aware of them for quite a long time but have not been able to apply them in a problem-solving context. Also included in the target group are students of the secondary education level who participate in school IT classes and fulfill the same knowledge requirements.

Differentiation, Restrictions, and Didactic Reduction

The original task consisted of four subtasks: finding a formula for the amount of color combinations for the upper row and in compliance with the combinations below for each maximum and minimum case. The final video was reduced to only finding the

maximum case. For solving the maximum case, tree structures and recursions are needed. The comparatively easier minimum case is presented at the end of the video as a task for the audience to practice and as a means of achievement test.

It is not the aim of this video to convey the principles and effects of the fundamental ideas of CS. Hence, an explanation of the presented principles is omitted deliberately. They are assumed to be familiar and understood. Furthermore, the video does not intend to focus on every single aspect and fact of the high performers' approaches. Some of the problem-solving processes of the high-performer group were highly individual and also very effective, but they are not appropriate to teach to novices. From all eight approaches, just those that represented a clear problem-solving structure and involved the principles of the fundamental ideas were included in the video. To be precise, the video contains approaches from the participants T10, T31, and T38 and focuses on "problem analysis," "problem-solving process," and "solution evaluation." Since the high performers did not comment the comprehension of the problem or the text, the video begins with analyzing the problem.

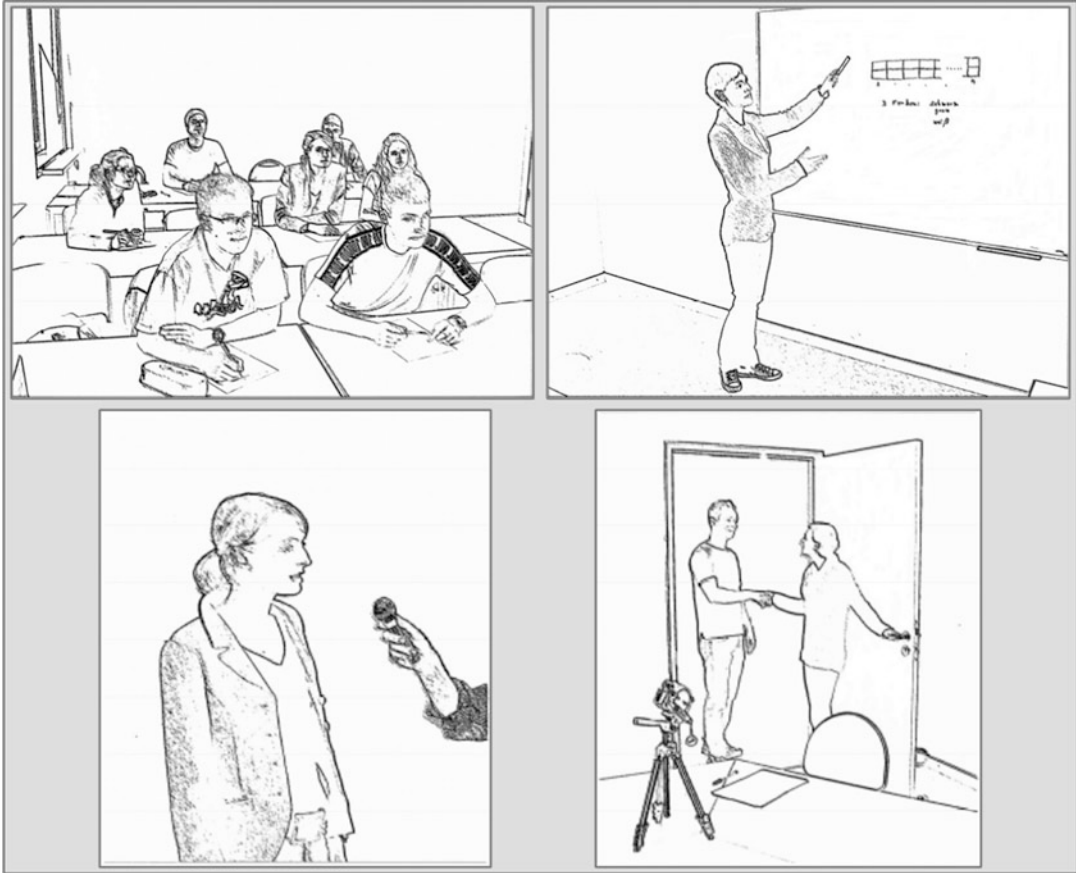
The video was didactically reduced especially at one section of the high performer's approaches in order to keep the complexity low. The derivation of the recursion formula, which is used to calculate the maximum amount of color combinations of the length n of the rectangle, was replaced by two mathematical conversions. In the problem-solving approach chosen for the video, two high performers developed the recursive base equations shown in Kujath (2008) by means of a tree structure. Afterward, the high performers set up a numerical series from the respective numbers of color combinations depending on the length n of the rectangle. These were then either calculated by counting the nodes of the tree structure, or they were calculated using one of their equations. Finally, the series of numbers made the high performers realize the underlying Fibonacci sequence. This process of inductive reasoning is needed to develop the generating scheme of the sequence of numbers. However, in the current example, it requires knowledge of the Fibonacci

sequence, yet for many low-performer students, this is not the case. Since the needed formula can also be developed by mathematical conversion of the recursive base equations, the video deviates from the actual approach of the high performers in this section. Thus, the formula can be found without any explicit knowledge about the Fibonacci numbers.

The Movie Script

Background Story From a media-didactic point of view, cinematic actions in which teaching content is embedded support the comprehension if used adequately. The educational core, which is presented below, is embedded in a story which presents the character of Tom – a high performer. The opening of the video, which is set up to look like a television report, starts by showing a group of students working on an exam task during a lecture. A short comment roughly explains the task, whereas an explicit explanation is put at the beginning of the educational part of the video. Afterward, some students are interviewed individually about their experiences with the given task. The students describe similar problems like the ones of the participants of the low-performer group. This aims at sensitizing the viewers to the topic and reconsidering their own problem-solving processes. Figure 2 shows four so-called scribbles in which scenes of the story are illustrated. Such scribbles help to visualize film scenes in the early planning stages. Typically, they are reduced to hand drawings with a pen just showing essential points of the scene with stick figures (Mair 2005).

Educational Core With Tom starting to solve the problem, the actual didactic part is initiated. The high performers' videos were analyzed with the focus in mind of finding distinctive and didactic helpful problem-solving activities. Afterward, those strategies were put together to one fictive, coherent, and optimized problem-solving process, which is depicted as a real situation in the video. One of the most important parts of the concept is to simulate the authentic work on the task. The viewer is supposed to be under the impression of sitting



Problem-Solving in Computer Science, Learning from a Gifted Peer, Fig. 2 Scene scribbles of the story. Group of contrast participants, top-left; explanation of the

problem by the investigator, top-right; individual interview after the exam, bottom-left; welcoming of the high-performer Tom in the lab, bottom right

right next to the high performer solving the problem.

The educational part is divided in two levels. On the first level, there is the specific problem-solving process showing Tom trying to find an answer to the given task. On the other level, an abstract comment level, Tom's preceding solving techniques are shown and explained. Both levels are shown alternately during the entire movie. At first, the task is presented. Afterward, the problem-solving process of Tom is shown on the problem-solving level. Just as done in the study, only his sketches and his corresponding verbalizations are shown. The original phrases were taken word-by-word as far as possible and smoothened and paraphrased if required. Additionally, verbalization from three different successful high

performers was put together coherently to create a comprehensive and complete overview of the succeeding problem-solving activities. If there were synonyms used to describe the same object – like the 1×1 -square was denoted by the subjects as “square,” “box,” or “field” – those terms have been linguistically harmonized.

At particular points, the display of the problem-solving level is interrupted to summarize preceding activities and explain them on the commentary level. All comments were written according to the recommendations for text comprehension given in Mair (2005) and Märtin (2005). In order to indicate the different levels, a clearly different layout and a shift between the speakers was used. During the animation, relevant parts of the original sketches as well as significant

formulations of the fictive problem were incorporated with the original voice. Afterward, the simulated problem-solving process continues at the problem-solving level. The dual presentation of the same content from two different perspectives – on the one hand the verbalizations during the process by Tom and on the other hand the animated explanation – ensures the necessary redundancies of the shown content. This supports the comprehension and the viewer's willingness to learn (Kittelberger and Freisleben 1994).

The Sequence in Detail In the following, the individual sections of the educational part are shortly introduced. A summarizing representation can be found in Table 2.

Explanation of the Problem For the reasons stated above, there are no verbal comments of the high performers about their problem and text comprehension techniques. Hence, the first module of the educational part provides an explicit explanation of the task of solving for the maximum case. It is important to make the viewers completely understand the problem task, since

otherwise they will not be able to follow the subsequent steps. This is accomplished by two things. First, little prior knowledge is assumed during the explanation. Second, the complex correlations are presented in simple consecutive animated graphics, which build on each other. The solution will not be provided, so that the viewer is able to create his own chain of thoughts during the video.

Analysis of the Problem The first activities of Tom shown in the material are supposed to provide an intensive analysis of the problem, in which the viewers can participate through Tom's verbalized line of thoughts. This essential phase of the problem-solving process was omitted completely by the low performers of the study. Tom considers the problem as a sequential coloring process and starts to draw a sketch which corresponds to the original papers of participant T38 of the study. Just like this participant, he scrutinizes how many possibilities exist to color the second upper box from the left. At the end of this phase, Tom comes up with the key finding of the diagonal relationship discussed in Kujath (2008).

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 2 Summary of the single stages in the educational part of the movie

Phase	Activities	Minutes
PC	T: Completed by the beginning of the educational part	0
	C: Full explanation of the task of finding the maximum case	3:00
PA	T: Preparation of a sketch to analyze the problem – considering the problem as a coloring process – recognition of significance of the color of the diagonally arranged squares – conclusion for next steps	2:30
	C: Animated original sketch of Tom – indication of importance of intensive problem analysis – explanation of key finding and its value for the problem	3:00
PSC	T: Successive development of a tree structure using the key finding – construction of the lower color sequence sought for – statement about the first part of the solution	5:00
	C: Transformation of entire tree sketch into an animated graphic – reference to the tree structure as an informatic problem-solving tool – explanation of construction principle of the tree – establishing relation between parameters of the tree and objects of the problem space	4:30
PSF	T: Analysis of completed tree sketch with focus on the recursive relationship of the number of nodes on each level – devising three base equations – mathematical conversion of base equation to formula sought for	4:00
	C: Transformation of Tom's sketch into animated graphic – explanation of Tom's thoughts during the analysis – reference to recursion as another informatic problem-solving tool – derivation of the three base equations – conversion of base equation into final solution	4:30
	Total time	26:30

PC problem comprehension, *T* Tom's activity, *C* commentary level with animated sequences, *PA* problem analysis, *PSC* problem-solving of lower color configuration, *PSF* problem-solving formula

In the following commentary part, advantages and motives of the preceding activities of Tom are discussed. The learners were taught that an intensive analysis of the problem leads to important insights for an efficient and successful work on the task. Furthermore, the key finding used later during the course of the video was presented to the audience.

Problem-Solving of the Lower Color Combination Now, Tom works on the lower color sequence, which leads to the maximum amount of possibilities of different color sequences in the upper half of the rectangle. It is demonstrated to the audience how Tom uses the findings from the analytical phase and thus, within just a few minutes, is able to create a continuously expanding tree structure to realize the maximum case.

This procedure is clarified in the corresponding commentary part afterward by deducting the tree structure gradually and with additional explanations. In this phase, the fundamental idea of structured dissection by trees as an informatic problem-solving tool is illustrated and explained using a concrete example. The commentary part explains how the single objects of the problem space can be modeled by a tree structure. For example, it is demonstrated that the height of the tree equals the length of the rectangle and the number of nodes on every level equals the amount of upper color sequences.

Problem-Solving of the Formula In the last part of the educational core, Tom turns toward the question about the formula for calculating the number of possibilities in relation to the length n of the rectangle. He develops a recursive formula by analyzing the tree structure created in the previous step. He does so by asking himself how he can derive the number of nodes on one layer of the tree from the number of nodes on the layer above. Finally, Tom quickly specifies the correct formula, and hence, the problem is entirely solved. Next to the idea of structured dissection, a second idea, namely, recursion, is demonstrated as a tool in this part of the movie.

Evaluation

Immediately after the development of the concept, a low-quality demo version was produced using Windows standard tools. The film sequences of the background story had been replaced by a picture story, which consisted of drawings made from photographs from the crucial scenes – like the interview or Tom's greeting in the lab. The animations were simulated in PowerPoint and screenshots of it were embedded in the video. This demo version was presented at a symposium and discussed in the department. The resulted proposed amendments were included in the consequently produced professional cinematic production at the audiovisual center of the University of Potsdam. In the final version of the video, only the presentation of the picture story was kept due to reasons of time and cost reduction. The comments were acted out by professional speakers (a male and female voice alternating). Furthermore, the animations of the explanation part were done in professional quality. As a result, we produced an instructional video in high quality of 33 min in German as well as in English language.

First Evaluations Through Surveys

In the first step of the evaluation, the finished video was assessed through a survey. Sixty first semester students of computer science and business informatics watched the video and afterward filled out a questionnaire. The form included questions about prior knowledge in informatics, self-assessment about problem-solving, comprehension questions about the context, and questions about the personal opinion on the video concerning understandability and appropriateness of the video as a teaching tool. Eighty-five percent estimated their ability to solve a problem as "weak" or "rather weak." Consequently, those students belong to the target group of the video. The results of the questionnaire showed a high acceptance of the concept of the video, and furthermore they signaled the demand of systematic teaching of specific techniques to solve problems. Most of the respondents stated that the video helped them to get

deeper knowledge on how to deal with problems of CS. Fifty-eight percent expressed higher motivation on working on informatic problems because of the video. More than 70% of the students would approve of also learning other methods with the same concept. The comprehension of the video as well as the length of 33 min was evaluated as “very good” on average.

First Study on Learning Effectiveness

While the questionnaire was aimed on the subjective opinion of the students, Schütze (2013) examined in his study whether the video material was indeed effective for the learning outcome. The study is specified in Kujath and Schütze (2015). The evaluation of the study was based on two hypotheses. The first hypothesis claims that subjects of the group “with video” are more likely to find a solution than the ones of the group “without video.” From the group “with video,” 25% of the test students provided a correct solution – random mistakes were adjusted – whereas just 18% of the students of the group “without video” could solve the problem. This confirms hypothesis 1 in Schütze (2013), however, with an insufficient level of significance. According to hypothesis 2, subjects from the group “with video” used at least one method shown in the video, resulting in higher-quality solutions. The analysis of the solution showed that 17% of the group “with video” used at least one tool provided in the video, whereas no student of the group “without video” used such techniques. Based on these results, the second hypothesis is not significantly confirmed but at least not refuted.

Summary of the First Results of the Previous Evaluations

The prior analysis verifies a didactic relevance of the video. Even though the personal perception of the participants of the questionnaire is subjective, the authors see the high acceptance of the target group toward the teaching tool as an important precondition for learning motivation. The study of Schütze (2013) indicates a high effect on learning as well. However, this should be confirmed by further studies.

Extended Study on Learning Effectiveness and Analysis of the Target Group

Design of the Study

Due to the small number of participants and the lack of significance of the results presented in section “[First Study on Learning Effectiveness](#),” a second study with considerably more participants was designed. The subjects were recruited in their first semester with an online application form. Similar to the previous evaluation, the students were asked about their prior informatic knowledge and their self-assessment about their ability to solve problems. For quantifying reasons, different informatic contexts (coding, algorithms and data structures, automata theory, tree structures, graph theory, and recursion) were listed and required to be judged by the degree of comprehension on a five-tier scale from 1 (not at all) to 5 (completely). The topics of “tree structures” and “recursion” were relevant for the study. The self-report of the ability to solve problems included the options “strong,” “rather strong,” “rather weak,” and “weak.” To identify the possible reasons for unspecific work on the task and lack of informatic problem-solving methods, the students were asked to put themselves in one of the following four categories of problem-solvers:

- A** = “I master informatic problem-solving methods completely and I am able to use them” – in the following called category “**A_{all}**.”
- B** = “I know informatic problem-solving methods and I know how to use them. However, I don’t know when to use them” – in the following called category “**B_{when}**.”
- C** = “I do know informatic problem-solving methods, but I don’t know how to use them properly” – in the following called category “**C_{how}**.”
- D** = “I don’t know any informatic problem-solving methods” – in the following called category “**D_{nothing}**.”

Composition of the Participants After eliminating invalidly answered online surveys, 66 participants had been invited to the study. They were

divided into 2 groups with 33 students each. Based on their answers in the categories “prior experience in informatics,” “ability to solve problems,” and “problem-solving categories,” the subjects had been divided pre-selectively to establish a parity composition regarding the (assumed) problem-solving competence.

In terms of the selection of questions stated above, the answers resulted from the single sub-groups and the overall group are shown in Tables 3, 4 and 5.

Discussion of the Tasks The first task contained a relatively challenging 3-coloring problem. In order to solve the problem, a tree structure could have been constructed. Based on that, a recursion

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 3 Informatic prior experience of the participants regarding tree structures and recursions

Frequency in the	Degree of prior knowledge regarding tree structures				
	5	4	3	2	1
Group “with video” ^a	0	11	14	5	2
Group “without video”	4	9	12	5	3
Total sample	4	20	26	10	5
Frequency in the	Degree of prior knowledge regarding recursions				
	5	4	3	2	1
Group “with video” ^a	1	10	13	7	1
Group “without video”	2	7	9	8	7
Total sample	3	17	22	15	8

^aIn the table based on the results of the questionnaire, the total number in the group “with video” is only 32 and not 33, because participant T133 from this group did not answer the survey

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 4 Estimation of own ability to solve problems

Frequency in the	Self-assessment of ability to solve problems			
	Strong	Rather strong	Rather weak	Weak
Group “with video”	0	15	17	0
Group “without video”	3	14	16	0
Total sample	3	29	33	0

would have helped to derive the formula to find the amount of possibilities to color the graph for an arbitrary n . This part of the test was supposed to show how the single participants of the different types would solve such problem without any further advice. The second task – a coloring problem, too – was solvable with the methods demonstrated in the video. However, a transfer of knowledge needed to take place to some degree. For example, the number sought for in this task could not be deduced directly from the tree structure and the recursion, but rather by adding another sub-tree. Hence, the direct use of the methods shown was not enough, and therefore, a simple memorizing of the solution example in the video did not lead to the solution of this task. Additionally, both groups were given an additional condition: “Solve the problem with the aid of tree structures and recursion.” This was supposed to establish an equality of chances between the problem-solvers of the category B_{when} (don’t know when) from the group “without video” and the group “with video” by providing them with a hint about possible problem-solving methods. Furthermore, the hint was to encourage the participants from the group “with video” to actually use the methods presented in the video.

Procedure of the Tests

Both groups had been invited simultaneously in two separated lecture halls. The aim was to investigate the change of the problem-solving behavior after the presentation of the video in a comparative study. Two different coloring problems were presented to each group. Both groups were provided with the problem which was solved in the video by the fictive high-performer

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 5 Distribution of the problem-solving types

Frequency in the	Problem-solving type			
	A_{all}	B_{when}	C_{how}	D_{nothing}
Group “with video”	1	10	16	5
Group “without video”	2	9	18	4
Total sample	3	19	34	9

“Tom” as the first task. The group that had not seen the video solved the second task directly after the first one. Both tasks and a short discussion of the solution can be found in the appendix. The second group, the group “with video,” watched the video after solving the first problem, however, without any didactic comments. Since the task shown in the video was identical to the one the students just solved, the authors hoped for a higher motivation and attention performance. Directly after the video presentation, the group “with video” was asked to solve the second problem (For the sake of completeness, it must be added that the group “without video” also watched the video. However, they have seen it just after the test and after handing in their solutions.). Additionally, the test persons were requested to comment shortly on their work. The students had 35 min for each task.

Evaluation of the Solutions

Both authors independently evaluated all of the 132 solutions. They had no knowledge of the participants’ group belongings while evaluating. For the analysis, the pages with the solutions and the short comments of the participants were used. During the analysis it turned out to be problematic that subjects only gave very brief comments. Furthermore, the work on the solutions was not in chronological or textual order. To allow a significant as well as a secure evaluation, the analysis was restricted to explicit and evident structures.

Assessment Scheme and Discussion The solution drafts were examined separately and were classified into the following scheme:

- 1. Tree structure and recursion used completely, correctly, and employed to lead to the solution
- 2. Tree structure and recursion used just partially to some extent
- 3. Every other approach including “empty page”

Thanks to this method, the assessment could be performed comparatively fast and reliable based on the graphical sketches. The evaluation from both experts was mostly identical. In some cases,

different evaluations were unified in a subsequent discussion. Solutions unrelated to the context of the video were not considered in the study even though possibly leading to a solution. The evaluation resulted in two numerical values for each participant ranging from 1 to 3 for the work on the first problem and from 1 to 3 for the second problem. Hence, a qualitative improvement for the second problem existed, if the difference between the two problems was either +1 or + 2. If such an improvement occurred with a participant of the group “with video,” a learning effect is assumed. Since it is possible that improvements occur in the group “without video” as well (especially because of the additional hint), learning effectiveness caused by the video is only given, if improvements of the solution of the second problem are significantly higher in the group “with video.”

Results

Only 12 out of 66 participants (18.2%) used tree structures and recursion from the very beginning, that is, without any clues about the methods. Five of them (7.6%) solved the problem completely and correctly. Despite a few exceptions, the remaining 54 solutions did not involve any specific informatic methods. They were mostly worked on by simply trying every color combination and did not lead to a quantifiable success. Hence, these problem-solvers correspond to the target group of the video.

For the second problem, many improvements were noticeable in the assessment scheme explained above. In the group “with video,” 19 out of 33 participants (57.6%) showed an improvement in their approach as well as 11 out of 33 participants (33.3%) within the group “without video” (see Table 6):

These findings equal a significance level of 5%. If one takes the degree of the solution

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 6 Improvements of the solution w.r.t. groups

Group	Participants	Improvements	Percentage
“With video”	33	19	57.6%
“Without video”	33	11	33.3%

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 7 Degree of improvement

Frequency in the	Degree of the solution improvements (dosi)				
	-2	-1	0	1	2
Group with video	1	2	11	15	4
Group without video	0	1	21	11	0

improvements (dosi) into account, that is, to which extent the solution improved, an improvement by the value of 2 occurred for 4 out of 33 participants (12.1%). There are no occurrences of this type in the group “without video” (0.0%). In both groups, a small number of deteriorating solution approaches were noticed which shall not be commented here. These observations are summarized in Table 7.

Who Benefits Most from the Video?

In the following chapter, we aim to investigate how those participants who improved their approaches in the second coloring problem can be divided using the selection criteria described in section “[Composition of the Participants](#),” i.e., “informatic prior experience,” “ability to solve problems,” and “problem-solving types.” The following tables include the percentages of subjects who improved in every single answer category. This is supposed to verify and specify the target group definition.

Prior Experience in Informatics By using prior experience with tree structures as an example, it shall be demonstrated how prior experience in CS affects the individual’s learning success. Table 8 shows how many participants out of the total number of the respective criterion per group improved their approach during the second coloring task. For clarity reasons, the values explained in section “[Composition of the Participants](#)” regarding the prior knowledge were combined in the following manner: the values 5 and 4 equal to “high,” 2 and 1 equal to “low,” and the value 3 corresponds to the attribute “intermediate.”

The group “with video” includes the most participants with an intermediate degree of prior knowledge about tree structures. 64.3% of the

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 8 Percentage of improvement by prior knowledge about tree structures

Who has improved? Distribution by prior knowledge about tree structures			
Group	“High”	“Intermediate”	“Low”
“With video”	63.4% (7/11)	64.3% (9/14)	42.9% (3/7)
“Without video”	46.2% (6/13)	25.0% (3/12)	25.0% (2/8)

participants (9 out of 14) showed an improvement after watching the video. In the group “without video,” it was only 25% (3 out of 12). Furthermore, the other participants of the group “with video” performed better as well. 63.4% of the participants of the group “with video” with a high degree of prior knowledge improved their approach in the second task compared to only 46.2% of the group “without video.” Concerning the participants with a low degree of prior knowledge, 42.9% of the group “with video” were able to improve in contrast to just 25.0% of the group “without video.”

In the group “with video,” participants with a high or intermediate level of prior experiences benefitted most according to these results. Participants with low prior experiences performed significantly worse in comparison. In the group “without video,” a high degree of prior experience about tree structures seemed to be inevitable in order to deal with the given problem.

Self-Assessment None of the participants considered his or her skills in problem-solving as “weak.” Table 9 shows how many participants of the respective criterion of each group improved their approach in their second task. Most of them belong to the categories “rather strong” and “rather weak.” Since there was no participant of the group “with video” who considered himself “strong” or “weak,” a statement cannot be made here.

Regarding the group “with video,” 60% of the “rather strong” category and 58.8% of the “rather weak” participants improved their approach after watching the video. According to the present data, the “rather strong” problem-solvers improved slightly more. In the group “without video,” the participants who consider themselves as “rather

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 9 Percentage of improvement by self-assessment

Who has improved? Distribution by self-assessment				
Group	Strong	Rather strong	Rather weak	Weak
“With video”	0.0% (0/0)	60.0% (9/15)	58.8% (10 /17)	0.0% (0/0)
“Without video”	33.3% (1/3)	21.4% (3/14)	43.8% (7/16)	0.0% (0/0)

Problem-Solving in Computer Science, Learning from a Gifted Peer, Table 10 Percentage of improvement by problem-solving categories

Who has improved? Distribution by PS categories				
Group	A _{all}	B _{when}	C _{how}	D _{nothing}
“With video”	0.0% (0/1)	80.0% (8/10)	56.3% (9/16)	40.0% (2/5)
“Without video”	50.0% (1/2)	44.4% (4/9)	27.8% (5/18)	25.0% (1/4)

weak” improved the most. With 43.8% it is significantly higher than in the section of the strong problem-solvers.

Problem-Solving Categories For didactic implications, it is of high importance to be able to assign the problem-solver to one of the problem-solving types mentioned above. We are going to investigate how the problem-solving types distribute among the participants who have improved in the second task (Table 10).

In the group “with video,” there were ten participants of the problem-solving type “B_{when}” (don’t know when), which means, according to them, they are able to use informatic problem-solving methods, but they are uncertain about when to use them. 80% of these participants showed an improvement after the presentation of the video compared to just 44.4% of the group “without video,” which is less than half of that group. A similar ratio is found in the category “C_{how}” containing those participants who, according to their statement, are aware of certain methods but do not know how to use them properly. Sixteen participants belonged to this category and watched the video. 56.3% out of them improved their work in the second part. The group “without video” included 18 participants from this category of whom 27.8% improved their approach. The present data suggests that participants from the problem-solving type B_{when} benefit most from the video material.

Summary and Perspective

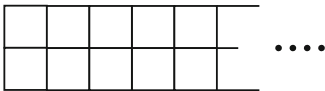
There is a high demand for targeted teaching of problem-solving competences especially for weak problem-solvers. The isolated presentation of informatic problem-solving methods on an abstract level (like “a graph is a 2-tuple ...”) is not regarded as sufficient, most notably by first-year students. To close this gap, a learning tutorial was produced, which illustrates the approach to informatic problems by a very strong problem-solver dealing with a coloring problem. The chosen form of presentation with a fictive high performer who thinks aloud while solving this problem was considered as positive and motivating by most of the test persons. The results of the present analysis of the learning effectiveness are very likely to not be random considering the significance level of 5%. They prove the learning effect of the tested video. Furthermore, it should be considered that the video was shown without any further comments and the participants were asked to solve the second coloring problem directly afterward. With appropriate didactical preparation before and after the presentation, the video is expected to be even more effective. Hence, a teaching unit about tree structures and recursion in a specific problem-solving context is going to be constructed, during which the video will be used as an introductory example. During the course of the unit, the video content will be further consolidated.

Furthermore, the question which type of problem-solver benefits most of this kind of video, and thereby the question of further clarifying the target group description, was investigated in this study. For the interpretation of the data, the participants' self-assessment statements were assumed to be sufficiently valid. As expected, the group which estimated their prior experience about tree structures as "high" or "intermediate" performed best after watching the video – the ones with an intermediate level even slightly better. For learners with low and no pre-knowledge, the video is rather unsuitable. The "rather weak" and "rather strong" problem-solvers performed equally well. However, a statement about the "weak" and "strong" problem-solvers cannot be made as there were no participants present in the group "with video." It can be said though that learners with a certain ability of problem-solving strategies are more likely to have a positive benefit from watching the video. Contrary to expectations, there was a high degree of improvement of the problem-solving type B_{when} from the group "with video" (compare Table 10). The percentage in this category is almost twice as high in comparison to the same problem-solving type in the group "without video," even though those participants were provided with the hint about tree structures and recursion as well. This suggests that the self-assessment was not sufficient enough, meaning that many participants did not know how to use informatic problem-solving methods and had to be taught first via video. Consequently, in future studies the self-assessment and the question about the problem-solving type in particular should be replaced by valid test data.

Appendix

Task 1 (35 min)

A horizontally lying rectangle of length n is divided into two rows and n -columns of 1×1 -squares:



Each of these 1×1 squares is supposed to be colored in one of the following colors: white, gray,

and black. Squares which meet at one of their edges cannot have the same color.

Another condition applies: The lower half of the horizontal rectangle is already colored in an arbitrary color sequence. How many different options to color the upper half correctly are possible?

Answer: The amount depends on the length n of the rectangle and the texture of the color sequence in the lower half.

- (a) How does the lower color sequence need to be colored to achieve the highest amount of coloring possibilities?
- (b) How can one always achieve the highest amount for every n ?

(Hint to solution (not for participants): The approach in the video is as follows: first, there is an in-depth analysis of the task. This leads to the awareness that the maximum amount of coloring possibilities can only be achieved if two colors appear alternatingly in the lower row. Thus, a decision tree can be constructed, which displays the color options of the upper row with growing length. Based on this tree, the formula of the maximum amount of possibilities can be derived:
 $A_n = F_n + F_{n-1}$)

Task 2 (35 min), after presentation of the video:

We encode positive integers 1, 2, 3, 4, etc. with the digits 1 and 0.

The common rules for binary numbers apply and there is no leading zero. Additional rule: In the 0–1 sequences, two 1s cannot be directly in a row.

Allowed: 1, 10, 100, 101, 10000, 1001, ..., 10010100010100010101010001, etc.

Not allowed: 1011

These sequences of numbers represent the natural numbers in the order of appearance. Consequently, 1 encodes 1, 10 encodes 2, 100 encodes 3, 101 encodes 4, 1000 encodes 5, etc. The digit sequences are sorted first by length and then by lexicographical order.

(Hint to solution (not for participants):

Again, a tree structure can be used to model the possibilities for the first numbers. The tree structure also helps to recognize the Fibonacci numbers. Fibonacci numbers always occur by adding a new digit, $1 = 1$, $10 = 2$, $100 = 3$, $1000 = 5$, $10,000 = 8$, etc. Similar to the first problem, the formula for the number sought for can be derived from the tree structure. However, on the lowest level the addition of a sub-tree is necessary. The correct number is **2000.**)

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Program

- [Information and Communication Technologies in Chilean Schools, from Enlaces to the Present Day](#)

Program Source Code

- [Programming and Coding in Secondary Schools](#)

Programming

► [Programming Misconceptions at the K-12 Level](#)

Programming and Coding in Secondary Schools

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Synonyms

[Coding](#); [Debugging programs](#); [Program source code](#); [Writing programs](#)

What Is Programming?

Programming, also referred to as coding, is the process of writing, testing, debugging/troubleshooting, and maintaining the source of code of computer programs. This source code typically consists of a list of instructions that can be compiled into an executable computer program. The source code is written using a programming language, often with the aid of an integrated development environment (IDE). The target platform on which a specific program can be executed, as well as many of the features or behaviors that can be encoded, is often dependent on the specific programming language and IDE used.

Programming Languages

A wide variety of programming languages are used in secondary schools worldwide. Many different factors play a role in determining the choice of language used. These include the familiarity of teachers with a particular language, the available hardware and/or software, whether the focus of the curriculum is on information

technology competencies or on computational thinking, and many other factors. Popular choices could include (Kemp 2014):

- Visual languages – Languages like Scratch or Kodu are often used at both primary and secondary school level to introduce pupils to programming concepts.
- General-purpose textual languages – Languages like C# or Java are popular options and allow a very wide range of possible applications to be developed.
- Declarative textual languages (markup) – HTML and CSS are languages used extensively for Web development. These languages do not support computational problem-solving directly; however, they are often used in combination with languages such as JavaScript to provide computational abilities.

Outcomes in Secondary Schools

There have been many attempts to make some form of programming education ubiquitous among school learners. Projects such as “Hour of Code” (hourof-code.com) have introduced millions of learners from more than 180 countries to basic coding in efforts to “demystify” the concept of programming. However, for most secondary school learners worldwide, formal programming education is, at best, an optional subject.

The primary aim of programming education in school is usually not to teach technologies, since these technologies change rapidly, but rather to teach problem-solving skills and the ability to think computationally. When students program, they have to firstly construct a solution to a given problem in the form of an algorithm. This solution then, secondly, has to be communicated in the syntax of a chosen programming language in a way that is perfectly unambiguous (Saali 2012; Szlávi and Zsakó 2006). This aids in the development of both logical thinking and the means to communicate clearly (Hromkovič 2006).

Computing at school (computingatschool.org.uk) breaks the process of computational thinking into the following components (Kemp 2014):

- Decomposition – breaking a problem up into smaller subproblems
- Pattern recognition – finding similarities in the behaviors and states you are modeling
- Abstraction – reducing the functionality/actions taken to the absolute minimum required
- Pattern generalization – defining concepts in their simplest form in order to reuse these in future problems
- Algorithm design – constructing a solution to the specific problem

International Trends

In the past, many national curriculum statements for secondary school programming education focused on the technology aspects related to programming. In recent years there has been an increased focus on the aspects related to the development of computational thinking and less focus on technology-specific aspects. There is also an increased international recognition of the need for most learners to possess basic programming skills in order to be considered digitally literate.

Cross-References

- Competency Models in Computing Education
- Computational Thinking
- Computers in Secondary Schools
- Computing Education, Practices in
- Curricula in Computer Science
- International Olympiads in Informatics
- Mobile Computing and Mobile Learning
- Problem-Solving in Computer Science, Learning from a Gifted Peer
- Programming Languages for Secondary Schools, Java

- Programming Languages for Secondary Schools, Python
- Social Media and Networks as Digital Instruction and Learning Platforms
- Teaching about Computing
- Teaching with Computing, Educational Games
- Value of Teaching Computer Science

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Programming Contest

- International Olympiads in Informatics

Programming Context

- Programming Misconceptions at the K-12 Level

Programming Experience of Irish Students

- Prior Programming Experience of Undergraduate Computing and Engineering Students in Ireland

Programming Language

► [Teaching Computer Languages in Universities](#)

Programming Language Selection for University Courses

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Synonyms

[Algorithmic language](#); [Computer language](#); [Computer programming](#); [Computer-oriented language](#); [Computing language](#); [Software development](#)

Definition

Programming language selection refers to the process of choosing a language for use in the initial programming courses in an academic curriculum.

Introduction

The choice of pedagogical programming languages for introductory or advanced computer science, information systems, or informatics courses is a major decision that requires considerable thought because the programming language used in a teaching environment can significantly impact not only how courses are taught but also their effectiveness.

An ideal situation would be a single language that could be used to cover all needed paradigms and topics in at least the first one or two programming courses rather than using different languages

in each course. Kummerfeld and Kay (2003, p. 105) note that “students using an unfamiliar or new programming language waste considerable time correcting syntax errors.” In the authors’ experience, it can take 4 or more weeks of lectures and coding exercises to teach students a second programming language, course time that could be used to cover other essential topics.

This entry examines aspects of academic programming language selection with the goal of aiding academics in choosing a language that will meet the needs of their curriculum. A sound choice will both provide a solid introduction to basic programming skills and quickly elevate those skills to a level at which informatics, software engineering, and computer science majors can be more effective in subsequent computing courses.

We start by considering the language selection decision-making process that an academic program needs to conduct, detailing a number of factors and external pressures that faculty might need to consider. Finally, we touch on some emerging trends that may affect choices and changes in coming years.

The History of Language Selection

In 1978 the ACM Special Interest Group on Programming Languages (SIGPLAN) sponsored a conference on the History of Programming Languages (HOPL), during which it was proposed that language importance should be assessed based on the following criteria: (1) the language has been in use for at least 10 years, (2) the language has significant influence, and (3) the language is still in use (Bergin and Gibson 1996). A study by Soloway et al. (1989) attempted to find a better match between a language and an individual’s natural skills and abilities, exploring the relationship between the preferred cognitive strategies of individuals and programming language constructs.

Howatt (1995) proposed an evaluation approach for programming languages, with criteria that included the broad categories of language design and implementation, human

factors, software engineering, and application domain. Howland (1997), too, presented an extensive list of criteria that the author considered to be important in choosing a language for introductory computer science instruction but concluded that the selection of a programming language should be made primarily on the basis of how well key programming concepts may be expressed in the language.

The Computing Curricula 1991 recommendations for the introductory programming course were examined by King (1992), and he reviewed the creation of several important languages as well as the emergence of various programming paradigms during the 1980s before going on to propose his own set of criteria for the selection of programming languages.

By the turn of the century, both the object-oriented (OO) paradigm and the recognition of the importance of information security were greatly impacting language choice. In a study of language selection for CS1 and CS2 classes, the Ad Hoc Advanced Placement Computer Science (AP CS) Committee (2000) noted three main requirements: emphasis on object orientation, need for safety in the language and environment, and a desire for simplicity. Wile (2002) pointed out that programming language choice is subject to both technical and social pressures, including those of the problem domains the languages are intended to address, the conceptual and computing models that underlie the designs of the languages themselves, independent of their particular problem domains, and the social and physical contexts in which the languages are used. Roberts (2004a) observed that an increasing number of universities were adopting Java as the programming language for their introductory course, not only because of the growth in the popularity of the OO paradigm but also due to the decision by the College Board to use Java in the AP CS program. Roberts (2004b) went on to reflect that two additional challenges were negatively impacting pedagogy: (1) the number of programming details that students must master had grown, and (2) the languages, libraries, and tools on which introductory courses depend were undergoing more rapid

change than in the past. Finally, Gee et al. (2005) noted a divergent trend toward the use of scripting languages to teach programming concepts because they provide not only a proper programming environment but also a tool for the formation of active web pages.

Selection Approaches

Some languages were developed with the intent of solving problems, while others were designed to make teaching algorithms easier (Parker and Davey 2012). This has led to two often conflicting alternatives about which languages should be used in university courses: should academics choose a language that is commonly used in industry, or should they choose a language that best supports concept development in students? Thus, throughout the history of language education, there have been two distinct arguments for language selection: pragmatic versus pedagogical.

Pragmatic Approach

The pragmatic approach favors choosing a language that will assist students in getting a job upon graduation. This approach views the language selection approach's most important consideration to be a language's industry acceptance as well as the marketability of individuals proficient in its use.

Industry Acceptance

Industry acceptance refers to a language's market penetration in industry (Riehle 2003), i.e., the extent to which a language is used in business and industry. Sometimes referred to as industrial relevance, this can be determined based on current and projected usage, as well as the number of current and projected positions. Stephenson (2000) rates this factor as the greatest influence in language selection, as indicated by 23.5% of schools participating in his study. Lee and Stroud (1996) note that real-world acceptability once had little weight, as indicated by the earlier use of ALGOL and Pascal, but that attitude seems to be changing. Their opinion is that students

having an industrially accepted language on their resume is a significant consideration. A 2001 survey of all Australian universities indicated that perceived industry demand was the major factor in their selection of an introductory language (de Raadt et al. 2003). King (1992) concurs that many language decisions are made on the basis of current or projected future popularity, noting that there are a number of practical benefits to choosing a popular language including greater student motivation to study a language that they have heard is in demand, as well as a good selection of books and language implementations available for more popular languages.

Marketability

Marketability refers to high employability of graduates. This may include regional, national, or international marketability, depending on the placement of a program's graduates. When language selection is driven by demand in the workplace, i.e., what employers want, not only can that factor into improving the likelihood of quality future employability, but it can also increase student enthusiasm when studying a language if they feel it may improve their employability (de Raadt et al. 2003).

Language marketability is considered in several studies. In the census of introductory programming courses conducted by de Raadt et al. (2003), the most commonly listed factor in language selection (by 56% of the participants) was the desire to teach a language that equips graduates with marketable skills. Watt (2000) notes the need for transferable skills that will be useful in the students' future careers, while Emigh (2001) contends that the primary concern in language evaluation must be the demand in the workplace and employers' expectations of graduates. In fact, graduates' marketability can be further enhanced by exposing them to multiple languages (de Raadt et al. 2003). For example, a progression from C to C++ to Java will provide graduates with the qualifications for more advertised positions than exposure to any single language in isolation. Extrinsically motivated students aspiring to a lucrative career may

demand to be taught those tools that are currently in vogue in the industry, and in such cases, universities may have to accept that pedagogical issues in the choice of platform and language must be secondary to marketability concerns (Jenkins 2001).

Pedagogical Selection

Many academics question whether industry trends should drive changes in curriculum and programming courses as they often seem to (Smolarski 2003; McIver and Conway 1996; Howland 1997). Their stance is that decisions regarding the language used in an introductory course should be based on how well it underscores fundamental skills that help to make any student-developed software well-written and error-free as well as to prepare students for ensuing courses, rather than on what language is currently favored by employers (Smolarski 2003).

Avoiding the Complexities of Industrial Environments

These arguments also bring to the forefront the possibility that attempting to teach problem solving while simultaneously introducing a professional grade language into the first course conflict because students are distracted by difficulties associated with that language and its environment (Johnson 1995; Jenkins 2002; Gee et al. 2005; Allison et al. 2002; Kelleher and Pausch 2005). A language that requires significant overhead to address even trivial problems forces the language, rather than the techniques of problem-solving, to become the object of study (Zelle 1999).

Clear Problem-Solving Principles

A teaching language should be designed in such a way that it enhances teaching the fundamentals of basic programming tasks. This is the argument espoused by Wirth (1993), Kölling et al. (1995) and many other developers of teaching languages and is commonly invoked by proponents of the various "pure" teaching languages. The argument generally concludes that it is better to adopt a language not commonly used in industry.

Those sharing this viewpoint favor adopting a teaching language that promotes conceptual cleanness and efficiency as well as other instructional goals, rather than using a real-world production language whose rich feature set can introduce unnecessary complexity (Kölling et al. 1995).

Language Selection Process

Common problems that may be faced when designing an introductory course range from interdepartmental political squabbles if the course is a service course to logistical challenges if the course must accommodate a substantial number of students (Solntseff 1978). Clearly, strife surrounding the introductory programming language course and the language appropriate for that course has been ongoing for decades (Smolarski 2003). With no generally accepted approach for performing the evaluation, the selection of a programming language for instructional purposes is often a contentious task. The process often takes the form of an informal faculty discussion, with various faculty members championing their preferred language. The process continues until an eventual consensus is reached or the dominant faction wears down the opposition. As the number of faculty, students, and language options increases, this process becomes increasingly daunting. As it stands, the language selection process lacks structure and is seldom replicable (Parker et al. 2006a).

Many of the factors influencing the selection of a programming language for an introductory course at one US university is ably discussed in Smith and Rickman (1976), a study praised for its “comparable thoroughness” (Solntseff 1978). Parker et al. (2006a, b) examined over 60 papers relevant to language selection in academia and presented their criteria to be used when selecting a language for programming courses. Their study resulted in a selection approach that involves weighting each of those selection criteria based on its relative importance in each unique selection process.

Selection Criteria

Several factors should be considered when selecting a programming language. While different curricula place greater emphasis on different factors, generally all must be considered.

Parker et al. (2006a) compiled an extensive set of selection criteria and proposed a process for the application of those criteria to evaluate various languages to be used in programming classes. The selection criteria take into account the programming features of each language under consideration, the appropriateness of each of these features for teaching beginning (and perhaps advanced) programming concepts, the current and future industry acceptance of each language, the availability of quality textbooks, the costs associated with adopting each language, the infrastructure and support implications of each language, and the impact of the decision on the tactical and strategic direction of the department and curriculum. Parker et al. (2006b) carefully analyzed the preceding selection criteria. Those with commonalities were grouped together to produce the programming language selection criteria shown in Table 1, with a few enhancements added.

Reasonable Financial Cost

Reasonable financial cost refers to the price to acquire the programming language software and/or the development environment. While this may involve individual packages or a site license for a network version, educators should inquire about academic discounts for educational institutions, an alliance in which the university or department can enroll, or even a free, downloadable version.

Availability of Student/Academic Version

If a student version or academic version is available, students can install the development environment on their personal machine, making it convenient for them to work on their assignments even if the computer lab is not accessible. However, if the department has no option other than to use a network-based version because a student version is unavailable, students may

Programming Language Selection for University Courses, Table 1 Higher-order selection criteria

Software cost
Reasonable financial cost
Availability of student/academic version
Programming language acceptance in academia
Academic acceptance
Availability of quality textbooks
Programming language industry penetration
Stage in life cycle
Industry acceptance
Marketability
Software characteristics
System requirements
Operating system platform dependence
Source code availability
Student-friendly features
Development environment
Debugging facilities
Language pedagogical features
Ease-of-learning fundamental concepts
Coding safety and support for secure code
Advanced features for subsequent courses
Language intent
Scripting or full-featured language
Web development support
Mobile app development support
Language design
Target application domain support
Language paradigm
Methodology or paradigm support
Teaching approach support
Language support and required training
Availability of support
Instructor and staff training
Student experience
Anticipated experience level for incoming students

be forced to work on their assignments in campus labs, restricted by hours of operation, availability of transportation, etc. If an academic version has a limited feature set, then the benefit to the students may be considerably reduced, but a student version should at least be considered.

Academic Acceptance

Academic acceptance refers to the popularity of a language at other academic institutions. This can be gauged by assessing current or projected use at other institutions. For example, as OO programming increased in popularity and the College Board decided to emphasize Java in

the AP CS program, a number of universities, colleges, and secondary schools adopted Java as the programming language for their introductory programming courses (Roberts 2004a).

Availability of Quality Textbooks

The availability of quality textbooks is impacted by many factors. The life cycle stage of the language affects the availability of textbooks, because while it is often difficult to find a quality textbook for a newly released language, more textbooks become available over the time it takes for a language to mature. The academic acceptance of a language also plays a significant role in the availability of textbooks because the more widespread the use of a language in academia, the greater the textbook market for related textbooks. Publishers service that market by offering a larger selection of textbooks. Finally, textbook availability may also be affected by the teaching approach used. For example, functions-first, objects-first, or objects-early are all approaches used to teach OO languages, but fewer recent texts present the material from a functions-first perspective. Availability of reference books should also be taken into account (Lee and Stroud 1996).

Stage in Life Cycle

A language's stage in the programming language life cycle affects not only textbook availability, as discussed earlier, but it may also impact the widespread use of a language in both industry and academia. Universities generally prefer a language that is still in its earlier stages, rather than one like FORTRAN that is in its declining years. The programming language life cycle as described by Sharp (2002) is based on the natural principles of growth, maturation, and decay. The processes of natural advantage and evolution operate in the world of programming languages just as they operate in the biological domain, but in the case of languages, the main forces are efficiency of expression versus profitable adoption.

Industry Acceptance

As discussed earlier, industry acceptance is the market penetration of a particular language in industry (Riehle 2003). While many academic

programs place great emphasis on this factor, Howland (1997) objects that too many languages are chosen simply because of their current popularity instead of on a sound pedagogical basis.

Marketability

Marketability refers to the employability of graduates and was discussed earlier when pragmatic concerns were considered. Language selection is often driven by workplace demand because marketable skills influence future employability. Emigh (2001) cautions, however, that 2 or 3 years may lapse between when a student takes an introductory programming course and when he or she enters the workforce. Even curricula that adopt newer programming languages can make no guarantee that employers will still be using those languages when the students are hired.

System Requirements

The system requirements associated with a programming language or its development environment should be considered in the selection process. The amount of hard disk space needed for software installation, operating system compatibility, and the memory requirements for optimal software performance all factor into the decision. Both student and lab computers must meet the minimum requirements of the selected language.

Operating System Platform Dependence

Some languages are platform dependent, meaning that they will only run on systems using certain operating systems. For example, the Swift programming language can only be used on macOS, iOS, watchOS, tvOS, OS X, and Linux platforms. Other languages, such as Java, are platform independent, meaning that Java development environments are available for a variety of operating systems. Platform dependence may be a deal breaker for faculty members who are fanatic about a particular operating system.

Source Code Availability

Source code availability refers to whether a language and its associated development environment are open source or proprietary. Open-

source software allows users to modify, change, and share the source code. For example, PHP is an open-source language and can be easily modified by any member of the open-source community. On the opposite end of the spectrum, Microsoft is responsible for additions, deletions, or modifications in any of the languages supported by the .Net framework, while Sun is responsible for the ongoing evolution of the Java language.

Development Environment

Development environments range from simple text editors and command-line compilers to fully interactive and integrated development environments (IDE) (McIver 2002). The development environment can improve or impair productivity (Jensen 2004). Unless an IDE is easy to use, students may be distracted by the environment rather than concentrating on learning programming concepts (Kölling et al. 1995). However, well-designed programming environments assist students in learning to program (Eisenstadt and Lewis 1992).

Debugging Facilities

Although debugging facilities may be considered part of the IDE, when assessing a programming language, one should specifically evaluate the diagnostic aids associated with the language (Tharp 1982). Programming environments must contain extensive tools for tracing and debugging (Ad Hoc AP CS Committee 2000). Error diagnostics should be clear and meaningful (McIver and Conway 1996), and the language should not only be robust but must also be graceful in failure (Conway 1993).

Ease of Learning Fundamental Concepts

The learning curve differs greatly between languages or IDEs. For example, Python is widely considered to be simpler to learn than a .Net language like C#. Basic concepts include sequence, selection, and iteration, as well as arrays, procedures, basic input/output, and file manipulation. In addition to ease of learning, the language must have a concise syntax and straightforward semantics (Conway 1993).

Coding Safety and Support for Secure Code

Coding safety is assessed by whether the language offers features like strong type checking and array bounds checking while avoiding features like variants and pointers in unsafe mode. Kölling et al. (1995) note that a language should have a safe, statically checked type system, with no undetectable uninitialized variables and no explicit pointers. Support for secure code involves the inclusion of security-related features like Java's sandbox, which limits the memory addresses that a Java program can access.

Advanced Features for Subsequent Courses

Some academic programs use a single language to introduce basic programming concepts in an introductory course and then to progress to advanced concepts, like multithreading, in a subsequent course. In such scenarios, it is critical that the programming language includes sufficient advanced features to support an advanced programming course.

Scripting or Full-Featured Language

Educators may also want to consider scripting languages in addition to full-featured languages. Scripting languages like Python offer sufficient richness to cover most of the requirements of an introductory course while avoiding many implementation issues and reducing the complexity of the development environment. Full-featured languages, on the other hand, may offer a more complete set of language features that an instructor may want to address.

Web Development Support

Given the prevalence of web-based systems, it is essential that today's students have the skills to develop web-based applications. Programming languages offer varying levels of web development support. Web development capabilities are not limited to scripting languages, discussed above, but are offered by full-featured languages like ASP.Net that provide a high level of support for web development.

Mobile App Development Support

Today's students make extensive use of cell phone apps. The choice to consider mobile application

development limits the selection of languages that can be considered due to platform considerations. App development languages for Android are not the same as those used for Apple iOS app development. For example, two languages that have recently emerged are Kotlin and Swift. Kotlin is one of the official languages for Android development, while Swift was created by Apple to work with primarily iOS and a few additional platforms. More mainstream languages like Java, C#, and Objective-C can also be used for app development, but the field of language options is still narrowed considerably. Emulators and simulators for mobile design and development may help alleviate the platform issue.

Target Application Domain Support

Target application domain support could also be referred to as "problem domain." If the programming course is serving a particular problem domain, the extent to which a language supports programming for specific applications must be considered (Howatt 1995). Examples of application domains include FORTRAN's support for scientific programming, COBOL's support for business data processing, and RPG's support for report generation. If a programming course is being developed to serve Electrical Engineering, C or C++ may be the preferred language. If a programming course is designed to serve a data science program, languages known to support data analysis, like Python, should be considered.

Methodology or Paradigm Support

Methodology or paradigm support assesses how well a programming language supports the paradigm under consideration. For example, if the OO paradigm is being taught, then the language must support integral OO concepts like abstraction, polymorphism, inheritance, and encapsulation. Similarly, if the aim is to teach event-driven programming, then IDE support for a graphical user interface (GUI) and ease of implementing graphical components is essential.

Teaching Approach Support

Teaching approach support refers to how well a language supports the teaching approach

preferred by the faculty. For example, the intent of the course may be to teach programming concepts with the language simply serving as a vehicle through which those concepts are reinforced, or it may be to teach the features of a particular language, such as using C# to develop an advanced user interface.

Availability of Support

This refers to the availability of support staff, including tutors, computer lab staff, and network administrators, to support the teaching and administration of a language. Language evaluators must consider the likelihood that their language questions, as well as those of the students, will be answered (Cunningham 2004). This should also take into account the availability of support through forums or listservs on the Internet, as well as vendor support (Tharp 1982). The availability of other resources like teachers' guides, example programs, student workbooks, and programming assignments should also be evaluated. Support may also involve something as basic as someone who can install a language and its IDE on a server, so it is accessible to all students. It may also include the availability of student tutors who have previous experience with the language.

Instructor and Staff Training

The training required for instructors and support staff, the time needed to learn a language or its IDE, and the availability of qualified instructors to teach a particular language must also be taken into consideration. Adopting a new language requires a willingness on the part of the department to invest in training its instructors because they “must continuously enrich their qualifications and implement new training methods and techniques supplemented with practical methods and techniques supplemented with practical experience while teaching a new language that is as new to them as it is to their class” (Emigh 2001, p. 2).

Anticipated Experience Level for Incoming Students

The anticipated programming experience level for incoming students is important because students' previous experience and training can

positively or negatively impact their grasp of new programming paradigms and languages (Traxler 1994). If students coming into a program have been previously exposed to a particular language, then it may influence language selection. If a program consistently sees incoming students with little or no programming experience, it may be necessary to adjust its requirements and its programming language selection accordingly.

Developing Trends

Those performing programming language selection must be aware of trends that may require changes in course content. Educators must, however, take care not to be overly influenced by trends, because they are just that. Trends change from year to year, and educators must provide students with a firm grasp of the fundamentals of programming even at the risk of ignoring trends. That said, increased reliance on functional programming languages, the importance of data science, and mobile app development all have a potential impact on what is covered in courses.

Functional Programming

Functional languages use side effect free functions as a fundamental building block in the language, rather than objects or procedures.

Functional programming focuses on the application of functions to arguments. In fact, the main program is itself a function that is defined in terms of other functions. Functional programming has no implicit state and places its emphasis entirely on expressions or terms (Hu et al. 2015).

Functional programming was introduced in the 1950s and is experiencing a resurgence in recent years with the popularity of languages like Haskell, Clojure, and Scala driven by explosive growth in the use of smartphones and connected devices.

As computers, tablets, smartphones, and IoT gadgets become ubiquitous, servers can act as bottlenecks to performance. The functional programming model allows sections of software to more easily and efficiently run in parallel across different CPU cores or machines,

without requiring complex synchronization. This gives the functional paradigm an edge over the OO approach when doing concurrent processing such as web requests (Puryear 2016).

Functional programming is generally more difficult for students to comprehend than other paradigms. It is more intuitive for them to view the world as a group of interacting objects rather than attempting to model everything as functions. As such, the resurgence of functional programming may seem to be of little concern when selecting a language for introductory programming courses. However, it is relevant to this discussion because “there is growing interest among some academics to introduce functional programming and functional thinking as early as possible within the computer science curriculum” (Winter 2014, p. 33).

Data Science

Whether you call it big data, data science, data analytics, or something else entirely, it may seem incongruous to include it in a discussion of programming languages. However, as the importance of data science continues to increase, the programming languages used to support data science may begin to influence the selection of a language for programming courses. R and Python are two of the more popular open-source programming languages for data analysis, while Scala and Julia may also be encountered in this domain.

Python is of particular interest in this discussion because it is widely touted as being easy to learn in comparison with most other programming languages. Python is both easy to learn and simple to use (Newman 2012). Many features of Python facilitate both teaching and learning, such as a simple and flexible syntax, immediate feedback, easy-to-use modules, and strict requirements on proper indentation (Grandell et al. 2006). According to an analysis published on the ACM (Association for Computing Machinery) website, Python has become the most popular language for teaching introductory computer science in the United States (Guo 2014).

When taken together, the increasing importance of data analytics, the widespread usage of

Python in data analytics, and Python’s shallow learning curve have combined to result in many universities adopting Python as their introductory programming language.

Mobile App Development

The proliferation of smart phone usage and their ubiquitous phone apps have made mobile app development one of the hottest trends in software development. The thorniest issue, as addressed earlier, is the platform, since different programming languages are used to develop Android apps and Apple iOS apps. Android is available for dozens of smartphone models, meanwhile iOS only for a handful of iPhone and iPad models developed by Apple (Dogtiev 2017). At the time this was written, Android had 66.74% of the market, while iOS had only 31.46% (NetMarketShare 2017). Regardless of the platform chosen, projections show that by 2021, the total app downloads will jump to a stunning 352 billion (Dogtiev 2017). Mobile app development is a critical trend that may shape programming language selection for years to come.

Observations

The reality is that the choice of a programming language for introductory courses often involves compromise. While there are economic, political, and pedagogical factors that must be considered in the decision-making process, the importance of each of these factors may depend on the specific aims and priorities of the institution, educator, or course. Educators must be certain that none of the factors in the above criteria are neglected or sacrificed to more highly visible concerns (McIver and Conway 1996).

Language selection has long been a difficult and unstructured task. Few issues in the computing education world are as strategically important or as contentious as the choice of programming language (Jensen 2004). However, the programming language used in the introductory programming course can have a significant impact on how the course is taught as well as its effectiveness (Parker et al. 2006a).

Cross-References

- [Programming and Coding in Secondary Schools](#)
- [Programming Languages for Secondary Schools, Java](#)
- [Programming Languages for Secondary Schools, Python](#)
- [Programming Languages for University Courses](#)
- [Teaching Computer Languages in Universities](#)

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Programming Languages for Secondary Schools, Java

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What Is Java?

Java is one of the most popular and widely used object-oriented programming languages. According to the TIOBE index (See <https://www.tiobe.com/tiobe-index/>), which is an indicator of the popularity of programming languages, Java has been among the three most popular programming languages (together with C and C++) for 17 years in 2019 and currently holds and has been holding the top position over a long period of time in the past. The current significance is also confirmed by the annual survey conducted by Stack Overflow, which had more than 100,000 participants in 2018 (See <https://insights.stackoverflow.com/survey/2018>). Even with the perpetual increase in web development technologies, such as JavaScript and SQL, Java still plays an important role for all participants, from web developers and system administrators up to data scientists. Especially in Europe and India, it guarantees top-paying jobs (See <https://insights.stackoverflow.com/survey/2017>). Java was designed by James Gosling at Sun Microsystems

as a simple, object-oriented, distributed, interpreted, robust, secure, architecture-neutral, portable, high-performance, multithreaded, and dynamic language in the first half of the 1990s (See Sun Microsystems 1995), where it started as a part of a larger project to develop advanced software for consumer electronics and has since then been continuously developed further (initially by Sun Microsystems and since 2010 by Oracle after taking over Sun). The spread of Java began around the mid-1990s and thereafter at the time when the World Wide Web gained more and more popularity through web pages created with the Hypertext Markup Language (HTML), related web browsers with a graphic user interface (such as Mosaic and Netscape), and more and more devices being connected to the Internet. This resulted in the need for a compact, yet reliable, robust, and powerful language for developing programs for this scenario (See Claus and Schwill 2006).

The syntax of Java has been consciously oriented at C and C++ to simplify learning for programmers with knowledge of these popular languages and therewith to accelerate the spread of Java. The language provides the typical primitive data types for boolean, characters (char), integers (byte, short, int, long), and floating-point numbers (float, double), in which the different types of a category cover different ranges of values. In order to process many similarly structured data, arrays (or fields) with fixed limits are available. For other data types, Java offers a very extensive class library, e.g., for processing strings; managing data in stacks, lists, trees, or graphs; designing graphical user interfaces; or communicating in networks. In addition, there are numerous freely available class libraries on the net for a variety of purposes. To implement methods using algorithms, Java provides the usual control flow statements, with which elementary instructions can be composed. Elementary instructions are variable declarations with or without assignments, increments or decrements, method calls, or instance generations. Sequences of instructions can be formed for sequential processing. For the decision-driven execution of program parts, simple case distinctions with or without alternative

(if-then statement, if-then-else statement) or also with multiple alternatives (switch statement) are available. To control repetitions there are loops for iterating over a range of values (for statement) and over collections (for-each statement) as well as loops checking a condition before the execution of the loops' body (while statement) or after the execution (do-while statement). Program blocks belonging together are marked with curly braces ({...}). Both classes and methods can be defined using recursion. Constants and specifications can be combined in interfaces that are treated like classes; however they need classes for implementation. Classes and interfaces can be structured into semantically linked packages. A Java program then consists of a sequence of class definitions and interfaces, which can make use of the extensive Java class library and can, but not have to, be structured into one or more packages.

With Java, applications can be created, programs that can be executed directly with the Java interpreter, including apps for the operating system Android for mobile devices, and so-called applets, which are embedded in web pages and run, when a web page is displayed in a web browser. Applications need one single class to define a main method to indicate from where the program should start. Java supports all characterizing concepts of object-oriented development, as collected by Armstrong (2006), such as inheritance, object, class, encapsulation, method, method passing, polymorphism, abstraction, instantiation, attribute, information hiding, and dynamic binding (in descending order of use in definitions).

One of the main strengths of Java is that its programs can be run on all platforms for which an implementation of the Java virtual machine exists. This is the case, for example, for all relevant desktop operating systems. The reason for this is the goal of supporting network applications running on a variety of systems with different operating systems. To achieve this, the Java compiler generates a platform-independent object file format, which can then be executed in the respective Java runtime environment. The generated so-called bytecode is architecture-independent, but can be easily translated into machine code of the

executing machine and is thus efficiently executable. In order to allow the development of reliable programs, Java places great emphasis on the early identification of problems at compilation time (strictly typed language, compliance with class interfaces), loading time (testing of bytecodes), runtime (access to null pointers, violation of array limits), and the avoidance of error-prone situations. Therefore, language concepts such as pointer arithmetics, explicit reservation/release of memory, multiple inheritance in classes, and pre-processor statements were not included in the language design to simplify the development process. Because Java was designed for networked/distributed environments, great emphasis was also placed on security. Various security concepts have been implemented in order to prevent program manipulation by inserted parts. Applets from external servers are run in a closed environment (so-called sandbox). This prohibits access to the file system of the executing machine or the execution of programs and allows network access only to the source server. In the event of an infringement, the browser's security manager aborts the execution.

Java in the Educational Context

Java is widely used and omnipresent as a programming language not only in the field of software development as has been discussed in the former section but also in computing education at universities and secondary schools. At universities, Java is a popular language for the introduction into programming. To clarify the usage of Java in German universities, the authors conducted a survey in the first half of 2017. About 20% of those German universities responded where studying a subject related to computer science was possible. Regarding those universities, the proportion of universities for applied sciences vs. regular universities in our survey (69%:31%) was roughly the same as in the whole country (70%:30%). The geographic distribution of responses also adds to representativeness, since responses from 14 out of 16 states were gathered. Java was used in about 80% of

universities for teaching introductory object-oriented programming. Adding to that the number of cases where it is used in later advanced courses, usage of Java was reported in more than 90% of universities. Similar results could be obtained for upper secondary education, where it is frequently used as a text-based programming language after an introduction into programming with a block-based language (e.g., scratch, scratch.mit.edu) in middle schools. Regarding the spread of Java, there are national differences. In Germany, for example, Java is prescribed as the language to be used in central school-leaving exams of upper secondary schools in many of Germany's federal countries. The same formerly mentioned survey revealed that at least in upper secondary schools in half of all German states, Java was used as one of the text-based languages to teach concepts of object orientation. Of course, the spread in secondary education, higher education, and work life is linked: upper secondary education aims to prepare for future life situations by being practical and near to the learners' everyday lives and also for subsequent educational phases by following the principle of science propaedeutics. In higher computing education, too, programming languages are used, which are practically relevant for the graduates and which therefore create good job prospects. Because of its more than two decades ongoing development history, Java can be described as a mature programming language that implements the most important concepts of object-oriented programming in a neat way. Java's popularity and presence over a longer period of time have the consequence that there are numerous introductory and specialized textbooks and online offers such as tutorials or video courses available; in addition numerous research work on the development and testing of learning and teaching concepts for diverse target groups, pedagogically driven comparisons with other programming languages, empirical studies on learning difficulties and actions to avoid these, documented Java examples from various programming projects, and much more. There is also a wide range of freely available tools for Java programming from introductory integrated development environments with diverse visualizations up to

professional software development tools with integrated modeling tools and automated source code generation. The availability of all such resources on the WWW supports the learning of the language, and on various platforms, there is fast help for Java questions of any kind.

In secondary schools, Java has spread since the second half of the 1990s. The first documented teaching examples were often characterized by the attempt to implement imperative problem solutions using Java. Over the years, however, numerous high-quality teaching materials (e.g., school textbooks) have been published. In addition, various tools and learning environments have been developed over the course of time, which are apt to support teaching. The availability of such systems can, on the one hand, be seen not only as a strength with regard to instructional usage but also as an indicator of potential learning difficulties with regard to the language, since otherwise learning would be possible without such systems.

Among the systems for education, BlueJ (bluej.org) is a simple and compact programming environment for Java, which supports programming beginners through appropriate visualization of ideas of object orientation. For this purpose, the user is presented, for example, a visualization of the class structure, via which objects can be instantiated, which are then displayed in an object bar. These objects can then be inspected, and their methods can be executed including input of parameter values. BlueJ is therefore often used as an introductory programming environment for Java. Also noteworthy is Greenfoot (greenfoot.org), a widely used learning environment for Java. It can be used to create simple two-dimensional graphical applications. In certain scenarios, the learner is provided with basic functions, which can then be expanded step by step. Particularly interesting is the development of Stride in Greenfoot, a Java-based form of block-based programming. Learners who previously learned to use a block-based programming language can use it to create programs that are block-based, which makes the transition easier. The source code fragments assigned to these blocks can then be developed further on source code level. This allows a connection to didactic

concepts for younger learners. There have been also experiments with such interface concepts concerning subsequent educational phases. Thus, an earlier version of the professional programming environment Netbeans was able to open BlueJ projects, thus simplifying the transition from an educational to a professional programming environment. The corresponding plugin, however, is not being further developed.

Because of its spread in the field of education, other successful and tested educational environments have been adapted so that they can be programmed with Java, and existing learning and teaching concepts can be reused. Among them are Turtle, Karel The Robot, Lego Mindstorms, Arduino, and others. In addition, a number of didactic class libraries have been developed that simplify or support Java's not very intuitive input and output and teaching concepts based on it.

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Programming Languages for Secondary Schools, Python

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Python is a high-level multipurpose programming language created by Guido van Rossum and first released in 1991. Python is open source and managed by the nonprofit Python Software Foundation (<https://www.python.org/psf/>) since 2001. Python is taught in secondary schools in many countries and is the most popular introductory programming language at top US universities (Gua 2014).

Python supports multiple programming paradigms, including object-oriented, imperative, and functional programming. There exist two versions of Python, which differ only in a few details but are not compatible, the original Python 2 and (since 2008) Python 3. All source code mentioned in this contribution is written in Python 3.

This contribution presents Python from an educational perspective, focusing on these two questions:

- In which way does Python support individual learning by experimenting and exploring?
- How can programming with Python help to develop high school student's computational thinking skills?

Computational thinking is an activity that is associated with problem-solving using a computer. It “represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use” (Wing 2006, p. 33). Selby and Woollard (2013) identified five basic facets of computational thinking: algorithmic design, abstraction, decomposition, generalization, and evaluation. These five concepts are used as a framework for the presentation of Python language features.

Experimenting and Exploring

The Python Shell

In the interactive Python Shell, learners can try out single Python commands. Python Shells are available on the Internet and can be used online (e.g., <https://www.python.org/shell/>).

A very common way to work with Python in the classroom is to use the integrated development environment IDLE (integrated development and learning environment). IDLE is part of the standard distribution, which is available for free and can be downloaded from the official Python website (<https://www.python.org>).

The Python Shell displays a command line starting with the prompt `>>>`. When a user enters a Python statement and hits the ENTER key, the Python runtime system interprets the

statement and returns the result in the following lines (read-eval-print loop, REPL). Examples:

```
>>> 12 * 17
204
>>> round(12.34)
12
>>> 1 < 2
True
```

Introspection

Python supports exploring objects and classes by introspection. Each object has introspective attributes that begin and end with double underscores. These attributes make it possible to look inside objects.

Example: All classes have the attribute `__bases__` containing a tuple with all base classes the class is derived from. For example, the standard class `int` (integer numbers) is derived from the most abstract class `object`:

```
>>> int.__bases__
(<class 'object'>,)

```

There are some built-in functions for introspection. The function `type()` returns the class an object is an instance of:

```
>>> type(1)
<class 'int'>
```

The function `id()` returns the identity (a unique integer number) of an object.

```
>>> id(1)
496855168
```

Experimenting and Inductive Learning

Experiments are the basis of scientific knowledge acquisition. Inspired by observations researchers develop theories (models) about the world.

In an inductive teaching pattern, students try out function calls in the Python Shell first and verbalize an abstract definition of the effect of the function after this phase of experimenting.

Task: “Try out the following statements. Explain what the function `len()` calculates.”

```
>>> len([10, 4, 12])
3
>>> len("Washington")
11
>>> len([None])
1
>>> len("")
0
>>> len(3)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: object of type 'int' has no len()
>>> len([])
0
>>> len([[1, 2, 3]])
1
```

Experimenting in the Python Shell can help clarifying difficult concepts and avoiding misconceptions. For example, the idea of identity and the difference between mutable and immutable objects can be explored.

In Python, numbers are immutable objects. What is the effect of these two assignments?

```
>>> a = 1
>>> b = 1
```

Now there are two names (`a` and `b`) for the one and only object 1. This can be verified by checking the identities:

```
>>> a is b
True
>>> id(a)
1494706304
>>> id(b)
1494706304
```

In contrast to numbers, Python lists are mutable objects. They can change their states.

```
>>> s1 = [1, 2]
>>> s2 = [1, 2]
```

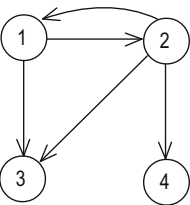
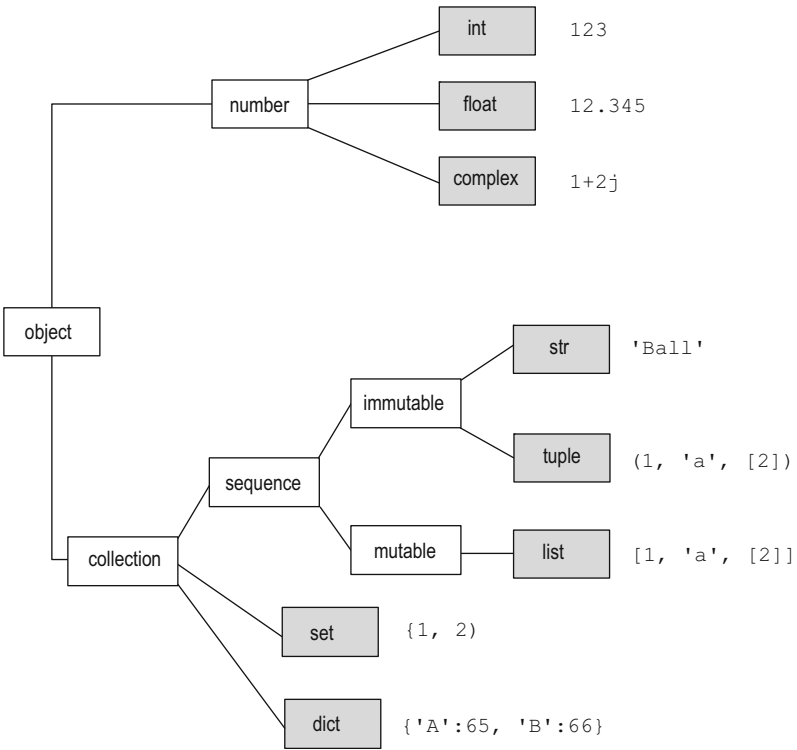
These two assignments generate two equal but not identical objects:

```
>>> s1 is s2
False
>>> s1 == s2
True
```

Abstraction: The Python Type Hierarchy

Computer programming includes abstraction. The programmer considers only those aspects of a scenario which are relevant with respect to the purpose of the project and ignores unimportant details (Fig. 1).

Programming Languages for Secondary Schools, Python, Fig. 1 An excerpt from the Python type hierarchy



$G = (V, E)$
 $V = \{1, 2, 3, 4\}$
 $E = \{(1, 2), (1, 3), (2, 1), (2, 3), (2, 4)\}$

Programming Languages for Secondary Schools, Python, Fig. 2 A directed graph with four vertices and five edges

Python standard types (built-in types) and corresponding operations provide a framework for modeling. For example, a Python list is a mutable sequence of items that can be objects of any type. Lists are used to model collections that can change their size. On the other hand, a Python tuple is an immutable sequence of items and may be used to model an entity that consists of a fixed number of elements. For example, a group of persons may be modeled by a list of tuples, each tuple representing name and age of a person (Fig. 2):

```
group = [("Anna", 16), ("Tom", 15),  
        ("Svenja", 15)]
```

A directed graph can be modeled by a Python dictionary, mapping each vertex to a list of adjacent vertices, for example, {1: [2, 3], 2: [1, 3, 4], 3: [], 4: []}.

Algorithmic Design and Basic Python Syntax Features

A program is an *implementation* of an algorithm that runs on a computer. It is also a verbal *representation* of an algorithm that is to be read and understood by humans. This section presents a few basic language features that help to increase the readability of Python source code.

Layout

The layout of a Python script has a semantic meaning. A block of statements is not defined by curly braces as in Java but by indentation. Lines of

code that start with the same number of leading whitespaces belong to the same block. The following script prints the first ten Fibonacci numbers. It consists of two blocks. (Comments start with a hash character # and are terminated by the end of the line.)

```
# Fibonacci numbers
a = b = 1           # first line of block 1
for i in range(10): # second line of block 1
    print(a)         # first line of block 2
    a, b = b, a + b  # second line of block 2
```

A statement is terminated by the end of the line.

Multiple Assignments

Multiple names can be assigned to an object in one single statement:

```
a = b = 1
```

It is also possible to bind multiple names to multiple objects in one single statement. For example,

```
a, b = 1, 2
```

has the same effect as

```
a = 1
b = 2
```

Swapping values can be implemented very intuitively:

```
a, b = b, a
```

Mathematical Conventions

Instead of individual comparisons that are connected by a Boolean and operation, like $(a < b) \ \&\& \ (b < c)$ in Java, Python programmers can use chained comparisons like $a < b < c$. This is a common convention in mathematics and makes conditions shorter and easier to comprehend.

```
if 18 < age < 60:
    print("The entrance fee is 10 EUR.")
else:
    print("The entrance is free.")
```

In mathematics there is a special notation for defining sets (set builder notation) using an output expression (e.g., $2 \cdot x$), a variable (e.g., x), an input set (e.g., $\mathbb{N}$), and a predicate (e.g., $x^2 > 3$). Example:

$$A = \{2 \cdot x | x \in \mathbb{N}, x^2 > 3\}$$

In Python a similar notation, which is called *set comprehension*, can be used.

```
A = {2*x for x in {1, 2, 3, 4, 5} if
x**2 > 3}
```

The same concept is used for lists (mutable sequences). List comprehensions allow to write sophisticated algorithms like Quicksort in a concise way focusing on the algorithmic idea.

```
def qsort(s):
    if s == []:
        return s
    else:
        pivot = s.pop()
        left = [x for x in s if x <= pivot]
        right = [x for x in s if x > pivot]
        return qsort(left) + [pivot] + qsort(right)
```

Assignments and Dynamic Typing

In Python an assignment has a slightly different meaning than in C or Java. The statement

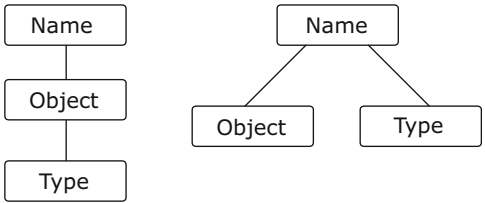
```
a = 3
```

means that the name *a* is bound to the object 3. An intuitive metaphor to visualize this is putting a sticky note with a name to an object.



In Java it would be necessary to declare the variable first. That means to connect the name “a” to a type, for example, integer. Only after this declaration it is possible to assign this name to an object.

```
int a;
a = 3;
```



Programming Languages for Secondary Schools, Python, Fig. 3 Typing in Python (on the left) and Java (on the right)

In contrast, Python adopts dynamic typing (“Duck Typing”). A name is connected just to an object but not to a type. However, objects are not “untyped” but they are per se connected to types (Fig. 3).

In Python, a literal representing an object of a certain type must be constructed according to certain grammar rules. So it is possible to recognize the type just by “looking at the literal.” For example, an integer number (in decimal notation) must start with a digit 1..9, followed by a sequence of digits 0..9 of arbitrary length.

Optional explicit typing is possible in Python since version 3.5.

Decomposition: Functions

Decomposition – breaking down complex problems by functionality – is considered to be a major facet of computational thinking (Selby & Woollard 2013). Defining functions usually is the first method of decomposition that students learn in a programming class. For example, a long sequence of instructions can be decomposed into definitions of functions and a “main program” consisting of function calls.

In Python a function is created by a `def` statement. Example:

```
def area (width, height):
    return width * height
```

If a `return` statement is missing, the function returns the empty object `None`. A function may be called with positional arguments:

```
>>> area(13, 10)
130
```

Another method of passing data is keyword arguments:

```
>>> area(width=13, height=10)
50
```

If meaningful names are used, keyword arguments can improve the readability of the function call by making it more explicit.

Generalization

In the context of program development, generalizing is the ability to recognize already existing pieces of software from previous projects that can be reused in new projects to solve new problems.

The Python Type Hierarchy

The Python type hierarchy illustrates the cognitive advantage of generalization. Operations are “as general as possible” and can be used for as many types of objects as possible.

Any object of a standard type can be tested for truth-value. “Empty” objects like 0 and collections with zero elements like an empty list [] are `False`. Nonempty collections and all numbers that are not 0 are `True`. This property can be used to write short conditions (line #1):

```
s = [3, 2, 32]
while s:
    x = s.pop()    #1
                  #read and remove the last
                  #element from s
    print(x)
```

Output:

```
32
2
3
```

Collection types include lists, tuples, strings, sets, and dictionaries. Objects of these types have common properties: They contain elements (items) and they are iterable. Any collection can be tested for membership of an object in the same way using the `in`-operation:

```
>>> 1 in [1, 2, 3]
```

```
True
>>> "I" in "team"
False.
```

The items of any collection can be iterated in a for-instruction:

```
>>> for ch in "sun":
    print(ch)
```

```
S
u
n
```

Objects and Classes

Object-oriented programming (OOP) supports generalization in several ways including overloading and inheritance. An object-oriented program is a system of objects that interact by sending and receiving messages. The program might be considered as a model of a piece of reality, say a library or a bank. In contrast to scientific models (e.g., atom models), the primary motive for creating an object-oriented program is not getting a better understanding of reality but creating a system that is easy to understand and to maintain. The following Python statement defines a class modeling traffic light with four states.

```
class TrafficLight:
    states = ['red', 'red yellow',
              'green', 'yellow']    #1

    def __init__(self):            #2
        self.index = 0

    def change(self):              #3
        if self.index < 3:
            self.index += 1
        else:
            self.index = 0
        return self.states[self.index]
```

Comments:

#1: This statement defines a class attribute. It is a list, representing the sequence of states of a European traffic light. Class attributes do not represent properties of individual objects but properties of all objects of the class.

#2: The name `__init__` is reserved for the constructor method of a class. The first parameter – usually called `self` – refers to the instantiated object. All methods must have this first parameter.

Students can develop a class definition with the standard Python editor IDLE and then store the source code as a file, for example, under the name `traffic.py`. This file is called a module. To test the class, a student may run the module in the IDLE environment. The Python Shell is then restarted. The student may create an instance of the class and try out method calls on the command line of the shell:

```
>>> t = TrafficLight()
>>> t.change()
'red yellow'
>>> t.change()
'green'
```

Modules

The class defined in the module can be imported and then used by another module. Example:

```
from traffic import TrafficLight
t = TrafficLight()
for i in range(4):
    state = t.change()
    print(state)
```

```
Output:
red yellow
green
yellow
red
```

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Overloading: Adopting Familiar Concepts

One method of generalizing is to use familiar concepts in new domains. For example, people are familiar with different types of addition since kindergarten. We can add numbers, strings, lists, physical sticks, etc. These are all different operations implementing one and the same abstract idea of “putting things together.”

In Python operators and built-in functions can be overloaded by defining “magical” methods with certain names starting and ending with two underscores. The following Python statement defines a class modeling physical length. It

illustrates the overloading of the plus operator. An instance of this class represents a length or spatial distance through a float number and a unit like cm or ft.

```
class Length:
    meter = {'mm': 0.001, 'cm': 0.01, 'm': 1,
             'in': 0.0254, 'ft': 0.3048} #1

    def __init__(self, value, unit):      #2
        self.value = value
        self.unit = unit

    def getMeter(self):                  #3
        return self.value * self.meter[self.unit]

    def __add__(self, other):            #4
        s = self.getMeter() + other.getMeter()
        return Length(
            s/self.meter[self.unit], self.unit)

    def __repr__(self):                  #5
        return str(self.value) + ' ' + self.unit
```

#1: This class attribute is a dictionary mapping units to the number of meters they represent. For example, 1 mm is equal to 0.001 m.

#2: A length object has two attributes, representing the numerical value and the unit of a length description.

#3: This method returns the numerical value of the length in meters.

#4: This method adds two length objects and returns a new object of the same type representing the sum. This new object has the same unit as this object.

#5: This method returns a printable representation of the object, like '15 cm'.

Defining a method named `__add__` means overloading the plus operator. Each time the Python interpreter evaluates an expression like `a + b`, it sends a message like `a.__add__(b)` to object `a`. In the same way, the developer can define further operations, including subtraction, multiplication, division, or Boolean functions like `<`, `>`, and `==`.

The class definition can be tested in the Python Shell. Example:

```
>>> Length(2, "cm") + Length(2, "in")
7.08 cm
```

Inheritance

Inheritance is a special form of reuse. A specialized class is derived from a more general base class. Instances of the derived class have all the attributes and methods of the base class plus additional attributes and methods. The following example illustrates how to derive a class modeling directed graphs from a Python dictionary.

```
class Graph(dict):                        #1
    """ Modelling a directed graph """

    def __init__(self):                  #2
        dict.__init__(self, {})

    def insertVertice(self, v):
        if v not in self.keys():
            self[v] = []

    def insertEdge(self, v1, v2):
        if (v1 in self) and (v2 in self) and \
            (v2 not in self[v1]):
            self[v1].append(v2)
```

Comments:

#1: The name of the base class (`dict`) is mentioned in parentheses.

#2: A new graph object is instantiated as an empty dictionary `{}`.

Students may create this program text using IDLE, store, and execute it. Then they can try out the new class in the shell window:

```
>>> g = Graph()
>>> g.update({1: [2, 3], 2: [1, 3, 4],
3: [], 4: []})
>>> g
{1: [2, 3], 2: [1, 3, 4], 3: [], 4: []}
>>> g.insertEdge(4, 3)
>>> g
{1: [2, 3], 2: [1, 3, 4], 3: [], 4: [3]}
>>> 1 in g
True
```

This dialog illustrates the advantages of inheritance: One can (re-)use methods that are inherited from the class `dict`. For example, one can extend a graph using the dictionary method `update()` and

print a representation of the graph using the “magical” method `__repr__()`.

Evaluation: Tracing and Asserting

A further facet of computational thinking is the ability to evaluate the efficiency and correctness of algorithms. This is a “high-level activity” that is not necessarily part of programming in the sense of implementing an algorithm. However, in “defensive” programming techniques, the possibility of bugs is considered already during the developing process. The programmer builds in certain protection mechanisms that make verification and error detection easier. Python supports tracing, test-driven development, and assertions.

Tracing

Normally, a python program runs in the “debug mode.” In this case the system variable `__debug__` has the value `True`. If the interpreter has been started with the `-O` option, it is executed in the “optimize mode.”

```
$ python -O myscript.py
```

In this case `__debug__` is false. The variable `__debug__` can be used to design a program, which explains to a human being how it works (tracing) in order to convince her or him that it is logically correct. The definition of a self-explaining Quicksort function may start like this:

```
def qsort(s):
    if __debug__:
        print("I am sorting", s)
    ...
```

Assertions

Python provides a feature for testing assertions, the `assert` statement. It consists of the keyword `assert` and a logical condition. Example (testing a precondition):

```
def area (width, height):
    assert (width > 0) and (height > 0)
    return width * height
```

During runtime (in debug mode) each `assert` statement is evaluated. If it is true, nothing happens. Otherwise the interpreter raises an exception.

Assertions can be used to check pre- and post-conditions. They may help to understand difficult algorithms (like Quicksort) because they relate complex concepts to simple (and intuitive) implications. For example, it is intuitively clear that sorting a list does not change the number of element.

Test-Driven Development: Doctest

The Python standard module `doctest` supports test-driven development (Beck 1999). When a programmer defines a function or a class, she or he can add a string at the beginning of the instruction block documenting the code like a comment (docstring). The docstring of a function can be used to define test cases by writing function calls and the expected results like in an interactive Python session. Consider a module containing a Quicksort function:

```
def qsort(s):
    """ Returns a sorted list of all
    elements of s.
    >>> qsort([2, 1])
    [1, 2]
    >>> qsort([])
    []
    """
    ...
```

```
if __name__ == "__main__":
    import doctest
    doctest.testmod()
```

In this example the docstring specifies two test cases. The first test case can be read “`qsort([2, 1])` must return `[1, 2]`.” If the module file is run directly (and is not imported), the last two lines of codes are executed, and the doctest system is activated. If the module is imported by another module, the docstring is ignored.

If one of the expected results differs from the calculated result, doctest raises an exception. If nothing happens, the function works fine for all test cases.

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Programming Languages for University Courses

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Synonyms

C#; C++; FORTRAN; Java; Python

Introduction

University computer science (CS) and information systems (IS) departments are under constant pressure to adapt various programming languages for their courses: Local software companies want graduates to be trained in whatever web development, scientific computing, firmware, or high-performance computing language they are using. Other companies want coders to maintain their legacy systems in COBOL or FORTRAN. Engineering and science faculty may want the introduction to computer science programming course taught in whatever programming language they use in their labs. Finally, CS and IS faculty want their students to learn how to code.

What Do Programming Languages Need to Provide for University Courses?

The first two courses in CS and IS curricula are Introduction to Programming I and II (CS-I and CS-II), the objectives of which are to teach basic programming concepts and creative problem-solving skills. The choice of programming languages in these courses first and foremost must facilitate these goals. The *structured* and *imperative* programming paradigms (Dijkstra 1975; Salus 1998) include the essential CS-I and CS-II concepts of data types, variables, arithmetic expressions, type conversion, if then else, for and while loops, strings, character storage (e.g., ASCII/Unicode), pass-by-value/reference parameters, run-time stack, and heap memory management concepts. The *object-oriented* programming paradigm (Salus 1998) also must be taught in both CS-I and CS-II. It includes classes, class instances, references, inheritance, constructors, class-level variables and properties, destructors, and simple dynamic memory management. More advanced CS and IS courses will need to teach the use of a few built-in classes implementing important data structures such as lists, stacks, and queues, as well as file and database access.

Beginning programming students also must learn how to creatively develop algorithms to solve new problems (Soloway 1986; Lister 2011). Writing code is a creative endeavor akin to composing music. A music composition class exposes students to classic examples of music like a Bach fugue or a funk beat and then requires them to creatively write new music. In the same way, the beginning programming class exposes students to classic algorithms such as the bubble sort or a linear search. Then students are expected solve different problems by creatively adapting the techniques in these classic algorithms to new situations. Traditionally, CS-I and CS-II include sorting, searching, and other basic algorithms (e.g., Kunth 1968).

Beginning programming students need to learn *hierarchical decomposition* (Yourdon and Constantine 1975). Even small programs of only 50,000 lines of code are unfathomably complex.

In the same way that the writer of a long research paper needs an outline to keep track of the paper's organization, coders need to learn how to break apart and organize their code. "Hierarchical decompose" is when the coder breaks up a complex problem into tiny sub-components. These tiny components are then developed as individual functions or classes and finally assembled into an "outline" that implements the complete solution. The structured programming paradigm divides large programs into small procedures or functions. The object-oriented paradigm additionally divides programs into classes. CS and IS students need to understand and use both of these hierarchical decomposition approaches.

One of the key aspects of the functional programming paradigm (Salus 1998) is the use of small, isolated "recursive" functions that are defined in terms of themselves. Recursion is another key coding skill that is essential for computer scientist students, as many algorithms and data structures are inherently recursive. Virtually any modern industrial programming language supports recursion and the functional paradigm. Figure 1 shows a recursive function implementing factorial. Note that it does not have any loops and it calls itself.

Programming students need to learn good *programming style* (Yourdon and Constantine 1975) which is an essential aspect of structured programming. Good style allows programmers to understand each other's code, facilitating debugging and modifications. Following many of the concepts developed in the structured programming movement, precise variable and function names are essential, allowing everyone on the team to understand what a function is intended to do and precisely what each variable contains. A good block comment needs to be

```
int fact(int n) {  
    if(n==1) return 1;  
    return n * fact(n-1);  
}
```

Programming Languages for University Courses,
Fig. 1 Recursive function implementing factorial

included at the top of each class or function (sometimes called a procedure, method, or subroutine). This block comment needs to include a single sentence describing the purpose of each class or function.

While not essential, it helps if beginning programming courses are fun and seem relevant. Key programming concepts and algorithms can be taught using *simple graphics* and often provide additional motivation for students. *Event-driven programming* allows students to see how their coding skills can rapidly create applications similar to those they use on their laptops and cell phones.

While computer science, information systems, and other engineering and science students are generally fairly computer savvy, a good programming language needs a helpful *integrated development environment* (IDE) for constructing, running, and analyzing code. The environment should be easy to install on virtually all laptops and home computers. It should be available to students for no cost. It should be easy to use and should facilitate learning how to code. Suitable development environments provide helpful error messages assisting students in locating syntax errors and helping them understand the causes of run-time bugs. A superb debugger is essential as it assists students in observing the code running, allowing them to see "inside" their code to better understand why bugs are occurring and what needs to be done to fix them.

Some have argued that an IDE explicitly designed for beginning programming students may be superior to an industrial tool such as C#'s Visual Studio or Java's NetBeans. However, we have found few disadvantages to these industrial tools for successful CS and IS majors and minors, and since these tools must be learned eventually in the workplace, we see little advantage in not introducing them early in the CS and IS curricula.

Industrial Versus Educational Languages.

The objective of university computer science (CS) and information systems (IS) programs is to *educate* students in key concepts and skills, not to *train* them to use all the features of particular industrial languages. Industrial programming

languages necessarily must include vast collections of built-in classes and other features for implementing complex data structures, file and database access tools, etc., features that are far beyond the scope of academic programs. Such advanced language features need to be learned on the job or through industrial boot camps.

However, fairly broad subsets of industrial programming languages such as Java, C#, C++, or Python allow CS or IS departments to provide solid coding pedagogy while creating sufficient skills with current industrial tools to allow students to obtain summer and part-time internships while in school and to function effectively in initial job settings. If an industry-popular language can provide the same educational experience as an academic-focused language, we suggest the industrial language is a better choice.

Academic CS or IS programs only have a limited amount of time to cover too many important subjects, and each additional programming language takes weeks of class time that could be used to teach additional skills. We suggest using a minimal set of currently popular, industrial programming languages that cover the needed educational paradigms, topics, and skills.

Which Programming Languages Are Best for CS-I and CS-II?

While virtually any modern industrial object-oriented programming language will allow the CS or IS instructor to teach CS-I and CS-II, some languages are much better than others for more advanced CS and IS courses.

C++. One of the top industrial programming languages is C++, particularly for low-level operating systems and firmware coding, as well as high-performance computing. However, the object-oriented programming concepts in C++ were added to the C language fairly early in the object-oriented movement, and these C++ object-oriented programming (OOP) features are somewhat arcane. Subsequent OOP languages such as Objective-C, Java, and C# correct many C++ shortcomings. Further, C++ has many “sharp”

```
int x = 3;
if (x=4) cout << x;
```

Programming Languages for University Courses, Fig. 2 Common C++ beginning programming bug. Outputs the integer 4

corners that can create complex bugs for beginning programming students. Figure 2 shows a common beginning programming bug or “sharp corner” caused by the use of “=” rather than “==.” Most programming languages do not allow an assignment statement to be used where a Boolean expression is expected or allow the integer side effect of that assignment statement to be used as a Boolean. Further, C++ uses pointers that contain actual memory addresses creating potential security issues, and C++ does not check array and string boundaries. Finally, C++ does not do much if any memory management of dynamically created class instances potentially causes memory leaks. Memory management thus must be taught at the same time as classes, making a complex topic more difficult.

It is not hard to transition from Java or C# into C++, and CS and IS students need to learn these other languages anyway. In our opinion, it is better to delay learning C++ until more advanced programming courses so students can first learn solid programming skills with a programming language with fewer “sharp corners.”

Java. Java is a solid choice for CS-I and CS-II and is used by many universities. Along with C#, Java is one of the top choices in the industry for application coding. Its syntax is similar to C++, but it has cleaned up virtually all of the C++ shortcomings, including multiple inheritance and memory management issues. It has fairly strong typing, forcing students to have to do explicit type conversion (e.g., typecasting), for example, converting a real number into an integer or string. While requiring a bit more work for the student, strong typing eliminates many hours of debugging and insures the students understand the underlying variable type and

arithmetic issues. A number of free IDEs (e.g., NetBeans) are available for Java that run on virtually all laptops and PCs.

There are some negatives with Java however. While event-driven programming with buttons, textboxes, list boxes, and the like is available in Java, they are a bit too complex for students to use in a CS-I course. We are also not familiar with any free high-quality automatic class diagramming tool for Java, the lack of which makes it more difficult to teach complex object-oriented design in CS-II. Java generally is not going to generate code that runs as fast as C++ making it less than ideal for high-performance computing courses, and it lacks a number of features making it less than ideal for a CS operating systems course.

C#. Microsoft created C# as its version of an object-oriented application programming language using C syntax and, in the process, avoided many of the problems with C++ and some of those with Java. C# is one of the most popular programming languages and an excellent choice for CS-I and CS-II. (We bundle both C# and Visual Basic under C#'s popularity as they are virtually the same, except C# uses "C" style syntax.) C# is a very "clean" language with which to teach CS-I and CS-II. It is strongly typed which helps students better understand arithmetic type conversions and casting operations. The Visual Studio Integrated Development Environment (IDE) is one of the best, and its debugger has no equal. There is a free automatic class diagramming tool within the IDE that can really help students visualize and understand complex OOP systems. C# and its IDE allow development of web and mobile applications, facilitate clean database interaction, and have a wide range of additional libraries available. The IDE provides excellent memory management of dynamically created class instances, allowing this topic to be taught separately from a student's initial exposure to classes. While not as fast as C++, its run-time environment can generate fairly fast code that is more than adequate for most situations.

Because C# is controlled by Microsoft, new coding concepts only come from their development teams, and generally they are very cleanly

thought-out and constructed. Microsoft provides C# and the Visual Studio software to universities and their students for free. And there are virtual machines that allow C# to run on Apple MACS and Linux machines. However running a virtual machine or dual boot Windows 10 on an Apple MAC can be a bit complex for some beginning programming students, and other solutions for running C# on non-Windows machines can be less than optimal. Finally some students and faculty are uncomfortable with learning and using proprietary languages.

Python. Python is an interpreted programming language that uses indentation to visually indicate blocks rather than traditional brackets in the C family of languages or Pascal's "Begin End" blocks. Python is a language that is designed to hide a great deal of what lies under the surface, allowing coders to stay focused on the algorithms being implemented. Python uses weak or dynamic typing or arithmetic, automatically converting between variable and expression types. While arguably less than ideal for students planning on majoring in engineering, science, CS, or IS who need to be exposed to lower-level issues in CS-I and CS-II, it might be better for a more general purpose survey of programming course. Some traditional CS-I data structures, such as arrays, are not implemented in Python, making it difficult to teach these concepts which CS, IS, engineering, and science students subsequently will need to learn if they are to transition to C++ or another more conventional programming language. Python has seen significant use in industry. Open-source IDEs and run-time environments are available as well as easy-to-use graphics packages that can be incorporated into CS-I and CS-II curricula.

Legacy Programming Languages. There is considerable legacy code still being used in industry including FORTRAN and COBOL. Occasionally someone from the industry will want a university to train its students to use these languages. Generally this is not ideal, and these languages should certainly not be used in early CS or IS courses; No CS or IS faculty will want to teach CS-I or CS-II using GOTO statements

(e.g., Dijkstra 1968) which are at the heart of FORTRAN and COBOL legacy systems. Essential CS-I and CS-II object-oriented programming concepts need to be covered in Modern OOP languages such as Java. Each new programming language requires weeks of class time to just barely scratch its surface, so any classroom time spent teaching legacy languages is time not spent covering data structures, algorithms, and other essential topics.

What Programming Languages Are Best for Advanced CS and IS Courses?

While choosing a programming language or languages for CS-I and CS-II is the critical initial decision, some subsequent CS and IS courses will require additional languages.

Systems Programming. C++ is the standard CS programming language for building operating systems and – along with C – for computer engineers writing firmware. C++ code is also very fast, making it the clear choice for high-performance computing. CS students *must* learn C++, as it is the clear choice both for a senior level operating system course and possibly for an earlier systems programming course that covers pointers and bit manipulation including shifts, masking, and bitwise “and” and “or.”

Assembly. While professional computer scientists will rarely write a line of assembly, they may write compilers which generate assembly or machine code, and they need the understanding of computer architecture that is best developed by writing some assembly. Writing assembly and building compilers allow the computer scientist to understand how their C++ or other high-level language code is compiled and thus how it needs to be changed to make it run faster. The particular assembly is not that critical: A number of teaching assemblies are available that work well. Alternatively, a small focused subset of an industrial assembly can be used.

Engineering and Science Programming. Numerical analysis, Monte Carlo simulations, or other mathematical modeling may require specialized high-performance programming languages.

Engineers, math majors, and others may want to learn C++ in a systems programming course taught after CS-I or CS-II or as part of a high-performance computing course.

Specialized Application Programming and PHP. Information systems students must learn how to build web and mobile client and server-side applications as well as learn how to build and access a relational database from code; computer science students almost certainly should as well. Both Java and C# are excellent for applications development. However, information systems must develop HTML and JavaScript skills. PHP is a highly specialized programming language used to develop web applications. A PHP web development course should be required for IS students and be an elective for CS majors.

Cross-References

- ▶ [First Programming Language in Introductory Programming Courses, Role of](#)
- ▶ [Programming Language Selection for University Courses](#)
- ▶ [Programming Languages for Secondary Schools, Java](#)
- ▶ [Programming Languages for Secondary Schools, Python](#)
- ▶ [Teaching Computer Languages in Universities](#)

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Programming Misconceptions at the K-12 Level

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Synonyms

Block-based programming languages; K-12 novices; Misconceptions; Programming; Programming context; Text-based programming languages

Overview

As computing today is included in many fields, there are many efforts, by science or national communities, to engage K-12 students in programming through national curriculums, many movements, and new programming tools. However, teaching introductory programming is not as successful as we would like it to be. Various assessments of student knowledge reveal flawed understandings of the taught concepts, which we call misconceptions. Misconceptions in programming refer to incorrect models of some programming concepts. Despite the emergence of a plethora of new programming languages, students experience the same or similar misconceptions as they did more than 30 years ago. Identifying misconceptions can be crucial to minimize or even prevent misconceptions for both teachers and students alike. Over the last few decades, numerous researchers have classified different types of misconceptions and the problems they cause when novices try to learn to program. Most studies about misconceptions are conducted at the undergraduate or graduate level using text-based programming languages, while there is a lack of similar researches at the K-12 level. As K-12 students are in the early stages of cognitive development and have fewer preconceptions than undergraduates or graduates, it is

reasonable to expect that they are not facing the same difficulties.

With the development of visual block-based programming languages, such as Scratch, designed for the younger generation of programming novices, there is a new scope of possible additional misconceptions and/or possibility to minimize known misconceptions. In comparison to the text-based programming languages, block-based programming languages have the advantage of eliminating syntax problems thus allowing students to focus on problem-solving instead of syntax. Besides focusing students on problem-solving, block-based programming languages offer new programming context like programming games, storytelling, animations, and other. Block-based programming languages enter into all educational levels (Mladenović et al. 2016a), but the most sensitive age group are K-12 programming novices. When educating K-12 programming novices' teachers should consider: students' age, the programming language used, the programming context, and the programming concept learned.

How do the above-mentioned new programming settings effect on misconceptions at the K-12 level? To answer the question posed, diverse aspects should be considered: (a) misconceptions developed by the K-12 students should be identified; (b) the impact of different programming settings on developing misconceptions should be detected. By considering mentioned aspects, educators should offer different teaching approaches for the basic programming concepts, like variables, sequencing, and repeating, to minimize or even prevent programming misconceptions.

K-12 Novices and Programming Languages

The term “programming novices” is mostly referred to the undergraduate students. What about K-12 programming novices? Abstraction skills are essential in programming. According to Piaget, abstract thinking is at the last stage of cognitive development in the formal operational stage (Piaget 1952). Therefore, K-12 children (7–11 years) are mostly at the concrete or pre-

formal stage of cognitive development while undergraduates are matured in logical reasoning (Sekiya and Yamaguchi 2013). Accordingly, the problems for many students start at an early stage of learning when they need to understand and apply the abstract programming concepts. Teaching K-12 novices should involve teaching and learning strategy that begins with the concrete in a context familiar to students and then gradually leads to an understanding of the abstract (Dann and Cooper 2009). Students understand what they can see, and if they cannot see what a program is doing, they struggle to understand it. The question we should ask is: How can we make abstract programming concepts concrete?

Novices programming languages should have simple syntax simplifying the learning process but at the same time a powerful means to introduce students to programming. Such programming languages are called mini-languages (Brusilovsky et al. 1997). The learning focus should be on language semantics not on the syntax itself.

Logo and BASIC are both considered one of the first micro-languages but with the different underlying philosophies. The Logo programming language is primarily designed to introduce children to programming, based on the constructivism approach, while the BASIC programming language is intended to be a teaching tool for undergraduate students and everyone interested in microcomputers. Many new programming languages arise from these two programming languages but with different approaches and goals.

Based on the programming language syntax, programming languages for K-12 novices could be classified into three groups: visual-text-based programming languages, procedural-text-based programming, and visual-block-based programming languages.

Visual Text-Based Programming Languages

“Turtle graphics” of Logo programming language (Papert 1980) is considered as one of the first mini-languages. The programming language Logo, created in the late 1960s, is based on the idea of the microworlds where the student, as a programmer, is controlling the actor in the microworld. The actor can be turtle, robot, sprite, and so on. The

main characteristic of such languages is the graphical output of the program execution in the form of, for example, moving the actor in the microworld.

Characteristic of the visual text-based programming languages is simple text-based syntax with the visual output of the program execution, usually represented in the microworld. Those languages are appropriate as the first steps in learning programming for children. As the “Turtle graphics” of Logo was one of the first such programming languages, the presented idea is widespread, so even Python contains the *Turtle library*, allowing using *turtle graphics* when programming in Python, as in the Logo programming language.

Programming context of the visual text-based programming languages is usually geometry but through concrete experience in the form of drawing different shapes by controlling the actor in the microworld. The visual output of the program execution allows students concrete to abstract experience because the execution of the text-based instructions is visible by moving the actor in the microworld.

Procedural Text-Based Programming Languages

The Logo programming language, a dialect of Lisp, was designed as a tool for learning. The name Logo derives from the Greek logos, meaning word or thought. In the same period of the Logo creation, the BASIC programming language also emerged. With the arrival of the microcomputers in the mid-1970s BASIC (an acronym for Beginner’s All-purpose Symbolic Instruction Code) started to become more popular. BASIC is text-based programming languages with textual input and output of the program execution. The original BASIC language is designed to facilitate students in fields other than science and mathematics to use computers.

BASIC could be considered as a predecessor of modern, similar programming languages. Nowadays, Python is more often used as a programming language for beginners because of the simple syntax and the increasing commercial popularity.

Programming context for procedural text-based programming languages is still based on

solving math problems such as arithmetics. As program input and output are text-based, abstraction is necessary to understand applied programming concepts.

Regardless of their simplicity, text-based languages are perhaps not suitable for the K-12 level students.

Visual Block-Based Programming Languages

In the last two decades, the new generation of the programming languages, designed for children, appeared. They all share the “Logo” philosophy (Papert 1980) with introducing the programming through microworld, representing the concrete manipulable world. The main difference, compared to Logo, is the visual, block-based input, where instructions are usually represented in the form of puzzles.

Characteristic of the visual block-based programming languages, such as Scratch, Alice, Blockly, Micro: bit, and so on, is manipulation with the visual objects on the screen instead of writing text instructions which is characteristic of text-based programming languages. Therefore, it is suspected that block-based programming languages require a concrete level of cognitive development while text-based programming languages require formal operation cognitive level. Besides, a feature of the block-based programming languages is moving programming context from math to programming games, storytelling, and so on. By moving programming context, students can explore the use of different programming constructs by, for example, programming games. By exploring, students have more information to understand the given problem which can result in various forms of cognitive scaffolding: from coding to feedback from playing the game. This process fits into cognitive disequilibrium. Programming settings such as programming language, context, and task (examples) should emerge an optimal level of students’ frustration to motivate students. Programming settings should be challenging enough to provoke an optimal level of frustration. Too hard programming settings can lead to further frustration and students’ overload, while too easy settings can lead to boredom.

Moreover, when programming in block-based programming languages, any programming concept can easily be introduced through programming games and so introducing students to all basic programming concepts during the first lectures. These programming language settings: game programming (or animations, storytelling, and such) using block-based programming language are enabling discovery learning (Bruner 1961). Problem-solving situations trigger discovery learning when the learner relies on his own experience and prior knowledge to solve the problem by interacting with the environment, exploring, and by manipulating objects. When programming games, a student needs to decompose the game scenario into the algorithm form to program it. Moreover, a student must manage the instructions, in the form of puzzles, to construct the program. In the case of the invalid program execution, the student needs to examine the program to find the errors. Through this process, students are using programming constructs without explicitly being aware of it. The teachers’ role is to reveal used underlying programming concepts to the students.

Programming Language Settings

Based on the program input, output, and programming context, programming languages can be introduced to the students in three basic approaches: visual block-based, visual text-based, and procedural text-based.

Table 1 presents a proposal of the appropriate programming language settings based on the cognitive level of the students.

If the learning content surpasses the cognitive level of the student, the student could reach the cognitive overload which can lead to low self-esteem, reducing motivation and success. Therefore, when choosing the appropriate programming language settings for K-12 novices, the teacher must take into account their age. It is beneficial for students to study the programming language that best fits their cognitive characteristics. By choosing the appropriate programming language settings, the teacher could boost the programming concepts learning, which could result in minimizing misconceptions, higher motivation, and satisfaction of the students.

Programming Misconceptions at the K-12 Level,
Table 1 Programming languages and cognitive development

Programming language settings	Piaget's cognitive development levels		
	Concrete	Pre-formal	Formal
Visual -> block-based (such as Scratch, Alice, hour of code)	Optimal	Not challenging	Not challenging
Visual -> text-based (such as LOGO, Python-using turtle library, Greenfoot)	Overload	Optimal	Not challenging
Procedural – > text-based (such as Python, BASIC)	Overload	Overload	Optimal

Otherwise, by introducing an inappropriate programming language, we could lose students for programming. For example, if the teacher presents a text-based procedural language too early for students’ age, most children could, due to the high frustration level, burnout and give up on programming. On the opposite, if the teacher uses block-based language at the level that children already outgrow, frustration level could be too low resulting in boredom and again possible giving up on programming.

Preconceptions, Misconceptions and Programming Languages

Students, considered programming novices, cannot be observed as “tabula rasa.” They have some preconceptions based on previous knowledge which can influence the learning process (Bruner 1977). Preconceptions can be perceived as naïve knowledge which can be easily corrected or removed, while misconceptions are considered as robust to change (Chi and Roscoe 2002). Students can assimilate utterly new knowledge, which is a

more straightforward process than the accommodation when new knowledge is not in accordon to existing schemas (Piaget 1952; Lister 2016).

However, preconceptions based on previous knowledge could lead to misconceptions in new learning context (White 2001). In this case, existing knowledge can interfere with the new one. This process fits into the accommodation process. Therefore, it is imperative to uncover students’ preconceptions to prevent potential misconceptions (Hyslop-Margison and Strobel 2007) for every individual student.

Accommodation is a process where new knowledge must accommodate existing models which do not fit in and can conflict with it. Accommodation can lead to cognitive disequilibrium. That happens when a student is holding two contradictory beliefs. For example, an expression $a = a + 1$ conflicts with the math preconception, where the mentioned expression represents the unsolvable math equation, while in programming, said expression presents assigning a variable value. To solve this cognitive conflict, students must adjust the mental model to accept new information. In the previous example, a student should modify mental model (math preconception) and accommodate additional information about variable value assignment. That is possible through examples of using the mentioned expression, through various examples of variable assignments including the use of different teaching methods, programming languages, analogies, and so on.

There is no doubt that K-12 programming novices have fewer preconceptions than undergraduate novices. By introducing students to programming as early as possible, we can prevent developing at least some misconceptions by helping them to accommodate new knowledge.

Misconceptions in programming refer to incorrect models of some programming concepts. Basic programming concepts are: sequencing, variables, branching, and repeating. Many studies on misconceptions are related to object-oriented concepts which are not appropriate for K-12 students. When it comes to teaching methods, it is essential to thoroughly adopt the basic concepts before moving on with new once. Mastering basic facts and then practicing more complicated ones is an excellent

way to turn a novice into an expert. Therefore, K-12 novices should master mentioned basic programming concepts shifting the teaching focus on the misconceptions of those concepts.

Some misconceptions are based on the syntax of the programming language. By using block-based programming languages, these misconceptions are minimized allowing students to focus on the learning programming concepts instead of struggling with syntax. Children under 12 are more likely to hold misconception than older children. When it comes to previous programming knowledge for children under 17, it is found that knowing Scratch as the previous language decrease tendency to holding misconception, while knowing other language increase it (Swidan et al. 2018). Furthermore, by programming in Scratch, as a block-based programming language, K-12 and high-school students can better understand some programming concepts, such as loop, compared to the text-based programming language (Weintrop and Wilensky 2015; Mladenović et al. 2016b; Li and Hoch 1974), and minimize misconceptions about loops (Mladenović et al. 2018). Though, when learning loops in block-based programming language, students mostly donot have to deal with variables. Moreover, it is noticed that when introducing to variables in Scratch to children between 7 and 17 years of age, it led to errors and difficulties. So, it is not surprising that there is a low percentage of using variables in Scratch projects (Swidan et al. 2018). When programming in Scratch, conditionals, and loops are used up to five times more frequently compared to logic and variables (Maloney et al. 2008).

Block-based programming languages could be an excellent entry to programming for novices, especially at the K-12 level, to meet the programming concepts, but at some point, they should transfer to the “real” text-based programming languages. Therefore, block-based programming languages could be an excellent tool for mediated transfer (Dann et al. 2012) to text-based programming languages. Variables are one of the basic programming concepts and the prerequisite for moving towards the more complex ones. As students mostly donot have to deal with variables when programming using block-based

programming languages, they end up with an incomplete understanding of expressions and operators (Grover and Basu 2017).

Misconceptions About Loops

Repeating or loop concept is one of the fundamental concepts in programming, which is known as a difficult concept for novices. Most programming curriculums, based on the “traditional” text-based programming languages are introducing programming concepts as follows: sequencing, conditionals, and repeating. On the other hand, in block-based programming languages and text-based programming languages with the visual output, such as Logo or Python using turtle library, the usual order of introducing the programming concepts is: sequencing, repeating, and conditionals. Although they share the same underlying idea, loop concept has a different kind of use in text-based and block-based programming languages. Prerequisite concepts for introducing the loop in the text-based programming language by the procedural approach are variables and sequencing. Although conditionals are not necessary, students should be familiar with this concept too to understand the termination of the loop execution. Sequencing is the only pre-required concept for introducing the loop in the programming languages with the visual outcome such as Scratch.

There are two kinds of loops: loops without conditional execution (such as *forever* in Scratch; *for* in Python and Logo) and loops with conditional execution (such as *repeat-until* in Scratch; *while* in Python). Table 2 shows the examples of the fixed bounded loops in Scratch, Logo, and Python. The outcome of all code examples is moving the *Sprite* (Scratch) or *Turtle* (Logo, Python) for ten steps.

Due to the simplicity of the repeat instruction, it is evident that the loop concept can be intuitively introduced in Scratch, while that is far more complicated in Python, especially for K-12 novices.

Loop concept is known as a difficult concept for a long time. Recent studies showed that students, who were programming using block-based

Programming Misconceptions at the K-12 Level, Table 2 Fixed bounded loops

Scratch	Logo	Python
	repeat 10 [fd 10]	<pre>for i in range (10): fd (10)</pre>

programming language, achieved significantly higher scores for the loop concept than students who were programming using a text-based programming language in high schools (Li and Hoch 1974) and elementary schools (Mladenović et al. 2016b, 2018). Moreover, it is noticed that when programming in Scratch, the least common misconceptions were related to loops and conditions (Swidan et al. 2018). Difficulties in loop understanding for text-based programming languages are syntax errors, misunderstanding of the scope of the loop, which lines should be repeated, how many times the code inside the loop will be executed, and so on.

A recent study, conducted in the K-12 school setting tested variable, loop, conditional, Boolean concepts in Scratch. These students previously completed introductory programming course using Scratch. They faced some misconceptions related to loops. In the case of a simple loop with multiple actions, researchers noticed that some students, instead to repeat entire sequence were repeating each action separately. This misconception is called the grouping actions in the loop. It is important to note that in this research, teachers did not spend time describing the changes of variables within the loop (Grover and Basu 2017).

Examples of Detecting Loop Misconceptions in Different Programming Settings

To detect misconceptions about loops at the K-12 level in several programming languages assessments should be carefully designed. As K-12 students are evaluated, the test should not be too complex or too long. To properly compare results, the tasks should be equivalent in all programming languages used. Multiple choice questions are appropriate, but incorrect answers should be designed to reveal some misconceptions. Table 3

shows examples of task and answers for detecting some misconceptions about sequencing and loop concepts in Scratch as block-based and Logo and Python, as text-based programming languages (Mladenović et al. 2018). The question is the same for all questions: How many steps will be made after the execution of the next code?

By analyzing students’ answers, some misconceptions can be revealed. Common students’ mistakes (misconceptions) are grouped into three groups. Table 4 shows detected misconceptions based on the questions showed in Table 3.

By analyzing results, it is found that students using Scratch achieved better results and had significantly fewer misconceptions about loops and sequencing for all tasks than students using Python or Logo. Significantly better results achieved in Scratch could be addressed to the visual representation of the instructions where is a clear difference between a loop and moving instructions in color and shape. Students had similar difficulties in Python and Logo programming languages. Only significant differences between scores in these two programming languages occurred in nested loops task (Q4). The mistake is more frequent in the Python group. Those students mostly had chosen the same wrong answer which refers to interpreting nested loops as two independent loops. As results achieved by Python students did not differ significantly compared to the results achieved by Logo students in the case of simple loops and two loops, this misconception can be addressed to Python syntax where all instructions within the loop are intended under the *for* instruction. This is not a problem for students in single loops, but when it comes to nested loop, the instructions under the inner loop are double indented which is confusing the students.

The programming language can influence the occurrence of the loops’ misconceptions. When

Programming Misconceptions at the K-12 Level, Table 3 Example of codes and answers in Scratch, Logo, and Python

Questions	Scratch	Logo	Python	Answers
Q1		<pre>fd 100 lt 90 fd 50 fd 50 lt 90</pre>	<pre>fd (100) lt (90) fd (50) fd (50) lt (90)</pre>	(a) 100 (b) 150 (c) 180 (d) 200 (e) 380
Q2		<pre>fd 10 repeat 10 [fd 10]</pre>	<pre>fd(10) for i in range (10): fd(10)</pre>	(a) 10 (b) 20 (c) 30 (d) 100 (e) 110
Q3		<pre>repeat 10 [fd 10 rt 10 fd 10]</pre>	<pre>for i in range (10): fd(10) rt(10) fd(10)</pre>	(a) 20 (b) 30 (c) 40 (d) 200 (e) 300
Q4		<pre>repeat 10 [fd 1 repeat 10 [fd 1]]</pre>	<pre>for i in range (10): fd(1) for i in range (10): fd(1)</pre>	(a) 10 (b) 20 (c) 100 (d) 110 (e) 1000
Q5		<pre>fd (1) repeat 10 [fd 1] repeat 10 [fd 1]</pre>	<pre>fd(1) for i in range (10): fd(1) for i in range (10): fd(1)</pre>	(a) 20 (b) 21 (c) 23 (d) 110 (e) 103

using Scratch, as the block-based programming language, K-12 students loops misconceptions are minimized, compared to using text-based programming languages like Python or Logo. As fifth and sixth-grade students are mostly still in the preformal phase of cognitive development, block-based programming languages, such as Scratch, offer them a concrete experience when learning hard programming concepts, in this case – the loop concept.

Misconceptions About Variables

Variables are maybe the critical concept that students should master when learning to program in text-based programming languages like Python or Logo. Understanding of variables is a prerequisite

for moving towards an accurate mastering of the basic algorithms like sequencing, branching (conditional execution of the program), and repeating. Therefore, students have difficulties with writing programs when they did not understand the functions of variables (Shi et al. 2018). Research reported that undergraduate novices while learning conditionals did not understand the purpose and ways to use the variables (Kwon 2017).

There is a lack of researches on this topic at the K-12 level. There are a lot of new block-based programming languages, like Scratch, minimizing the syntax problems while shifting the focus to problem-solving at the same time (Resnick et al. 2009). Besides, K-12 students have fewer misconceptions concerning loops using Scratch compared to text-based

Programming Misconceptions at the K-12 Level, Table 4 Students mistakes in scratch, logo, and python

Mistakes	Questions and answers	Scratch %	Logo %	Python %	Average %
Sequencing concept					
1. Adding the numbers within all instructions	Q1 (e) Q3 (e) Q5 (c)	6.53	25.87	23.37	20.77
Python example: fd (100) lt (90) fd (50)					
Students believe that the turtle will move for 240steps					
Loop concept					
2. Ignoring the instructions outside the loop	Q2 (d)	4.3	21.4	17.5	16.7
Python example: fd(10) for i in range (10): fd(10)					
Students believe that the turtle will move for 100 steps (10 × 10) ignoring the first fd instruction					
Loop concept					
3. Ignoring the nested loop	Q4 (b)	21.7	39.8	65.1	43.5
Python example: for i in range (10) : fd(1) for i in range (10) : fd(1)					
Students are interpreting two nested loops as two independent loops (20)					

programming languages Python and Logo (Mladenović et al. 2018). Hence, students mostly do not have to deal with variables when programming using block-based programming languages; therefore, they end up with an incomplete understanding of expressions and operators (Grover and Basu 2017). Therefore, it is not surprising that variables misconceptions are one of the top three misconceptions among K-12 level students using Scratch, while misconceptions related to control statements: loops and conditions are the least common (Swidan et al. 2018).

Although block-based programming languages are probably more appropriate for the K-12 level, due to syntax problem minimization feature, it is essential to transfer the programming process to the text-based programming languages at some point, which requires a focus on the variable concept.

Most researchers examined misconceptions among undergraduate students. We list the most common variable misconceptions into two groups:

Assigning the values: This group involves several known misconceptions about variables. For assignments such as $a = b$, the common mistake is the reversal assignment of the values (Du Boulay 1986; Putnam et al. 1986). For assignments such as $a = 100 + 1$, some students believe that variable a is holding unevaluated expression rather than evaluated value (Kohn 2017). Further, more the confusing example for students, such as $a = a + 1$ for this is unsolvable math equation, and as such, for many novices, it makes no sense (Bayman and Mayer 1983; Kohn 2017; Du Boulay 1986; Putnam et al. 1986). This misconception may arise from students math preconceptions (White 2001; Sorva 2018; Plass 2015).

Reassigning the value: Some students believe that variables can hold more than one value (Kohn

2017). For reassignments such: $a = 1$; $a = 2$; some students are repeatedly using the initial value instead of the last assigned value (Putnam et al. 1986), while some students believe that reassigned value adds to the initial value (Du Boulay 1986). Mentioned misconceptions are found in text-based programming languages, but they are also noticed in the Scratch programming language among school children (Swidan et al. 2018).

Examples of Detecting Variable Misconceptions in Different Programming Languages

To detect misconceptions about variables at the K-12 level, assessments should be carefully designed. As K-12 students are evaluated, the

test should not be too complex or too long. Multiple choice questions are appropriate, but incorrect answers should be designed to reveal some misconceptions. Table 5 shows examples of task and answers for detecting some misconceptions about variables in Logo and Python programming languages.

To determine misconceptions about variables, answers could be compared in both programming languages. Common students' mistakes (misconceptions) are grouped into five groups (Žanko et al. 2018). Table 6 shows those groups of misconceptions based on the tasks showed in Table 5.

Misconceptions related to assigning the variable values are 1 and 4 in Table 6. Assigning the

Programming Misconceptions at the K-12 Level, Table 5 Tasks and answers

Task	Python	Logo	Answers		
T1	a= 100 a = 20 print(a)	make a 100 make "a 20 pr :a	(a) 20 (b) 100 (c) a (d) 120		
T2	a =100 a = 20 print(' a ')	make "a 100 make "a 20 pr "a	(a) 20 (b) 100 (c) a (d) 120		
T3	a = 100 a = a +1 print(a)	make "a 100 make "a :a+1 pr :a	(a) 100 (b) a (c) a +1 (d) 101		
T4	a = 100 b = a print(a, b)	make "a 100 make "b :a (pr :a :b)	(a) 100 (b) 100 (c) a (d) a	b 100 b 100	
T5	a = 100 b = 20 a = 20 print(a, b)	make "a 100 make "b 20 make "a 20 (pr :a :b)	(a) 100 (b) 20 (c) a (d) 100	20 20 b 100	
T6	a= 100 b = 20 a= 5 print(a, b, b)	make "a 100 make "b 20 make "a 5 (pr :a :b :b)	(a) 100 (b) 100 (c) a (d) 5	20 20 b 20	20 5 b 20
T7	a= 100 b = 20 b = 5 print(a, b, b)	make "a 100 make "b 20 make "b 5 (pr :a :b :b)	(a) 100 (b) a (c) 100 (d) 100	20 b 5 20	5 b 5 20
T8	a = 100 b = 20 a = b b = a+1 print(b)	make "a 100 make "b 20 make "a :b make "b :a+1 pr :b	(a) 21 (b) a+1 (c) 20 (d) b		

Programming Misconceptions at the K-12 Level, Table 6 Common student mistakes probably related to misconceptions about variables

Mistakes	Tasks and answers	Logo %	Python %	Average %
1. Assigning the expression instead of the calculated value	T3 (c)	23.15	46.6	36.6
Python example:	T8 (b)			
<code>a = a+1</code>				
<i>Students believe that the variable holds the entire unevaluated expression as a string</i>				
2. Holding multiple values at a time	T6 (b)	31.5	34.9	33.5
Python example:	T7 (a)			
<code>a = 100</code> <code>b = 20</code> <code>b = 5</code>				
<i>Students believe that the variable b will contain the all assigned values (20 and 5)</i>				
3. When reassigning the variable value, assigning the sum value to the variable	T1 (d)	28.7	21.2	24.4
Python example:	T2 (d)			
<code>a = 100</code> <code>a = 20</code>				
<i>Students believe that the value assigned to the variable a will be the sum of every previously assigned value (120)</i>				
4. Using the symbolic name of the variable instead of its value	T1 (c)	20.38	17.78	18.88
Python example:	T4 (c)			
<code>a=100</code>	T5 (c)			
<code>print (a)</code>	T6 (c)			
<i>Students believe that the variable name rather than its value will print out</i>	T7 (b)			
	T8 (d)			
5. Using the first assigned variable value	T1 (b)	8.9	16.98	13.54
Python example:	T5 (a)			
<code>a = 100</code>	T6 (a)			
<code>a = 20</code>	T7 (d)			
<i>Students believe that the variable a will contain the first assigned value (100)</i>	T8 (c)			

expression instead of a calculated value is the most represented misconception. Misconceptions related to reassigning the variable values are 2, 3, and 5 in Table 6.

Assigning the expression instead of the calculated value was the most frequent misconception which was more highlighted in the Python than Logo programming language. These mistakes refer to the idea that the variable value is a string rather than its previous incremented value which is more highlighted in the Python group than in the Logo group. The mentioned mistake is the most frequent among detected misconceptions and the only one with statistically significant differences between programming languages

between detected mistakes. This finding could be addressed to the several facts:

- The misconception about equality sign is well-known programming misconception. Python expression $a = a + 1$ can be confusing and in a collision with the math preconceptions for programming novices, because such expression can be observed as the incorrect math equation. While trying to find alternative explanations for such expressions, students believe that variable holds an unevaluated expression ($a + 1$) as a string;
- Since the variables are not prerequisite for introducing sequencing and repeating

```
a='Hello world'
print (a)
```

Programming Misconceptions at the K-12 Level,
Fig. 1 An example of Python program

concepts, they are not the main concept in the Logo approach. Opposite, in the procedural-Python approach, variables are the main concept as it is prerequisite for introducing the sequencing, branching (conditionals), and repeating. Consequently, in the Logo approach the variable concept is separate, independent teaching topic with more attention to the concept itself, unlike than simply introducing in procedural approach as the necessary concept for more complex concepts like sequencing, branching, and repeating; Besides, the most common way to introduce the variable concept in the procedural approach is by assigning a string value, as Fig. 1 shows, which is not the case in Logo.

- Incrementing variable value is using in the sixth grade in the procedural approach when for loop is the teaching topic as part of the repeat concept.

Based on the findings revealed in the research, we can confirm that K-12 students may develop misconceptions about variables when using text-based programming languages. When teaching programming at the early stage, teachers should pay more attention to the variable concept taught by the procedural approach with the emphasis on the meaning of the equality sign in the programming and data types in order to minimize the appearance of misconceptions. Besides, more diverse examples of using variables should be used.

Conclusion and Implications for Teaching

Misconceptions of programming concepts are known for more than 30 years. Revealed misconceptions seem to be time resistant. By being

aware of the misconceptions that students can develop, teachers can have a positive impact on minimizing them by using different approaches such as using different programming languages appropriate for target age, changing programming context, using various task examples, and so on.

Most studies about programming misconceptions are conducted at the undergraduate or graduate level. There is a lack of such researches at the K-12 level. Although considered as programming novices, students are not “tabula rasa.” They have some preconceptions based on the previous knowledge. Preconceptions can lead to misconceptions if existing knowledge interferes with the new one. As K-12 students have fewer preconceptions, by introducing them to programming as early as possible, we can prevent developing at least some misconceptions by helping them to accommodate new knowledge.

Block-based programming languages could be the “soft entry” to programming, especially at the K-12 level. As block-based programming languages are syntax-error free, students and teachers can focus on learning programming concepts, such as sequencing, repeating, and branching, respectively. Although the use of the block-based programming languages can boost students’ understanding of the underlying abstract concepts of programming, students mostly donot have to deal with variables when programming in block-based programming languages. Therefore, students should, at some point, move to the “real” programming and transfer learned programming concepts to the text-programming languages. As variables are one of the main programming concepts in text-based programming, it is appropriate to start with it when introducing students to text-based programming languages.

In the end, it is up to the teacher to be aware of the programming misconceptions related to the programming environment chosen. By choosing proper examples, the teacher can create a situation in which students will be able to prevent or minimize the occurrence of programming misconceptions. No single programming language or tool can avoid programming misconceptions occurrence but choosing the appropriate one can lead

to better understanding of the teaching process that can cope with that problem.

Cross-References

- [Computers in Secondary Schools](#)
- [Programming Languages for Secondary Schools, Java](#)

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Project Management

- [Value of Teaching PRINCE2 Project Management Methodology](#)

Project Work

- [Agile Methodology in Education of IT Students, Application of](#)

Project-Based Learning

- [Agile Methods and Team Work in IT Education](#)
- [Multimodal Learning Analytics](#)

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses

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Synonyms

[Computer-based educational technology](#); [Information and communication technology \(ICT\) in education](#); [Quantitative synthesis of research](#); [Research evidence](#)

Introduction

In public discussions about the value of using modern technologies for teaching and learning, educational researchers and practitioners are expected to take steps beyond acknowledging fashionable trends emanating from the latest release of cutting-edge tools and applications. The real challenge is to explore more systematically and in-depth what really works in education for advancing students’ learning and to effectively link ever-advancing technological functionalities to educational theory and practice. Well-established pedagogical frameworks may or may not guide the effective use of various new educational technologies, and pioneering technological features may or may not make a difference in supporting deep and meaningful learning. Research in education intends to sort out these “mays” from the “may nots” in a serious effort to explain when and why seemingly promising

technologies lead to successful educational practices while others do not. This is the true challenge for primary researchers and the ultimate test for meta-analysts. The entire sequence of related meta-analytical studies addressing various aspects of effectiveness of educational technology is the content of this entry.

Why Meta-analysis

A meta-analysis (M-A) is a systematic synthesis of quantitative results from a collection of primary empirical studies focused on a given research question (or a set of closely related questions, typically of some applied value). A M-A achieves its goals by systematically collecting, sorting, extracting, coding, and analyzing data from the entire corpus of research literature in a certain focal area and, as such, follows a specific set of interrelated procedures (Cooper 2017). For a more detailed overview of the M-A methodology and practice (► [Methodological Quality of Educational Technology Meta-analyses](#)).

What sets an M-A apart from all other forms of literature reviews is that it combines the systematic nature of data collection and analysis with special statistical procedures for aggregating quantitative data (in the form of independent effect sizes) across a multitude of related primary research. This systematic data integration results in creation of an estimate of the central tendency, that is, a weighted average effect size, which is relatively independent from the respective sample sizes, compatible across collected studies, and reflects the overall effectiveness of an instructional intervention in question, thus informing educational practitioners of what to expect and what to prepare for in implementing it. In other words, as of now, M-A is regarded by some researchers as the most informative and, when implemented appropriately, the most reliable source of information for researchers and practitioners.

This entry provides a summary of findings from a series of related meta-analytical studies in the area of educational technology, namely,

- **Second-order M-A** of technology integration since 1984–2009 across subject areas and educational levels (Tamim et al. 2011).

- **Large-scale primary M-A** of classroom technology integration studies in post-secondary education (Schmid et al. 2014).
- **Follow-up M-As** that focus on subcollections from Schmid et al. (2014) addressing:
 - Blended learning (Bernard et al. 2014).
 - Designed interaction treatments (Borokhovski et al. 2012).
 - Pedagogical underpinnings of technology use in teacher education (Tamim et al. 2014).
- **Systematic review and M-A** of tablet use in educational practices – with or without a pedagogical framework – and their effect on learning outcomes (Tamim et al. [under review](#))

This entry provides a comprehensive overview of the array of important conceptual and applied issues that arise with respect to effectiveness (strengths and weaknesses, major purposes, etc.) of technology use to support various aspects of educational process. It offers some reflection on the progression of studies of educational technology – presented both as a summary of their results (derived from strong research efforts), and also as examination of how research questions have been evolving with the focus on different frameworks, types of technology, and conditions of its application for teaching and learning. The entry also discusses what can and cannot be explored by means of different types of M-As and where the most essential findings converge to inform educational practice.

The Evolving Role of Educational Technology

The reliance on computers in various aspects of daily life is a reality for many, and for them, its impact on nearly everything that is done, both personally and professionally, is significant. Why then are educational researchers still engaging in debate over its effectiveness for teaching and learning? Some, like Clark (1983), have insisted on a rather auxiliary role for educational technology (i.e., its functions are not unique, but can be equally effectively substituted by more conventional means of instruction), while others (e.g., Kozma 1991) have argued that its role in education is more substantive and

transformative. The disagreement is probably rooted in the history of educational technology itself.

Originally, technology was utilized almost exclusively to deliver instructional content, and as a medium it was no more effective than a human teacher, even not an especially experienced one. For instance, early studies on distributed closed-circuit television versus live teaching (Carpenter and Greenhill 1955) found no differences between live teachers and televised teachers. Even the development of much more sophisticated computer tools and applications (e.g., computer-assisted learning, multimedia, hypermedia) did not improve student learning outcomes enough for the issue to be considered and resolved unequivocally in favor of educational technology (e.g., Sitzmann et al. 2006).

It was the arrival of what Jonassen (1995) refers to as computer-based cognitive tools that appears to have tipped the scales from what can be achieved using multiple alternative media (i.e., Clark's argument) to what can be achieved primarily through computing (i.e., Kozma's argument). Computer-based communication, simulations, serious games, blogs and wikis, social networking, search and retrieval, and the like, promise unique benefits that go well beyond the simple transfer of content from the teacher to the student. Add to this productivity software like spreadsheets, statistical packages, concept mapping programs, and a host of other student-oriented applications, and we can see that Clark's arguments, while still valid in certain computing domains, must be considered insufficient for examining the overall benefits (and potential deficits) of the introduction and the continued use of computing in education. But even before turning attention to these more refined research question, it might have been expected that some meaningful closure should have been brought to the field with respect to several decades of primary research that tried to determine the overall effect on student learning achievements of educational technology in comparison with instructional practices that did not utilize any technological tools.

Second-Order Meta-analysis – Tamim et al. (2011)

By the first decade of the twenty-first century the amount not only of primary empirical studies but of various types of systematic reviews (including many M-As) accumulated in the field of educational technology, all focusing on nearly an identical research question: how much is using technological tools and applications more or less effective than not using it in classrooms (noting that technology use for the purposes of distance education is beyond the scope of this entry and all M-As that are revisited here). Navigating this vastness has become a real challenge that required some innovative and yet reliable approach to summarize important findings. Responding to this need, Tamim et al. (2011) undertook a second order M-A (i.e., an M-A of M-As) entitled “What forty years of research says about the impact of technology on learning.”

The second-order M-A approach offers the potential to summarize a growing body of meta-analyses, over a number of years, in the same way that a meta-analysis attempts to reach more reliable and generalizable inferences than individual primary studies (e.g., Peterson 2001). In this second-order M-A, 25 previously published M-As that cut across all levels of formal education, subject areas and technology types, from the 1970s to the present, were selected from a pool of about 75 M-As (by the criterion of the lowest possible overlap among primary empirical studies) and their results were synthesized. The random effects model analysis revealed a weighted average effect size of $\bar{g} = 0.35$ ($p < 0.01$), encompassing 1,055 primary studies and 109,700 participants. Moreover, this result was further validated through identifying and reanalyzing independent studies from these M-As that reported references to their respective “includes” (there were 574 independent effect sizes with the total number of students being 60,853) in the standard meta-analytical procedure. Remarkably, the overall weighted average effect size of this validation study (also according to the random effects model) was nearly identical to the

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses, Table 1 Mixed-effects moderator variable analysis of methodological quality of reviewed M-As

Methodological Quality Category	<i>K</i>	$\bar{g}$	<i>SE</i>	<i>CI</i> : Lower 95th	<i>CI</i> : Upper 95th
Low	8	0.42*	0.07	0.28	0.56
Moderate	7	0.35*	0.04	0.27	0.43
High	10	0.31*	0.03	0.25	0.37
Test of category differences		$Q_{\text{Between}} = 2.68$ ($df = 2$), $p = 0.29$			

* $p < 0.05$

one revealed in the second-order M-A: $\bar{g} = 0.33$ ($p < 0.01$), providing extra credibility for it.

In addition, two moderator variable analyses (mixed model) produced statistically significant outcomes. Technology use in K-12 formal educational settings (i.e., from kindergarten to final school grade before entering the post-secondary education for learners ranging in age roughly from five-six to seventeen-eighteen years) seemed to have higher effect on learning ($\bar{g} = 0.40$, $k = 9$) than it did in post-secondary education ($\bar{g} = 0.29$, $k = 11$): $Q_{\text{Between}} = 4.83$ ($p < 0.05$), and technology use in a general category “for instructional support” was more effective ($\bar{g} = 0.42$, $k = 10$) than it was in “for direct instruction” (i.e., content delivery) category ($\bar{g} = 0.31$, $k = 15$): $Q_{\text{Between}} = 3.86$ ($p < 0.05$). The latter result is of particular interest as it is capable of further informing practice (i.e., what kinds of pedagogical use of technology and various potential blends thereof are more promising), while opening the whole line of research on major purposes (i.e., key applied functions) of educational technology use that have produced some consistent findings, presented and discussed in more detail later in this entry.

There was another important outcome which, though it did not reach the level of statistical significance, clearly demonstrated a linear tendency for M-As of lower methodological quality (e.g., those that included studies of preexperimental research design or were implemented with some noticeable deviation from the best meta-analytical practices as outlined, for instance, in Cooper 2017 or Tamim et al. under review) to produce larger effect sizes, whereas effects of more rigorously implemented ones tended to be more modest in magnitude

(Table 1), the issue picked up in a related entry of this volume.

Thus, Tamim et al. (2011) addressed the question based on M-As that looked at the *technology* versus *no technology* question. The authors concluded that, generally speaking, educational technology does enhance learning, even if only to a relatively small extent.

However, this second-order M-A could not be considered the final word on the topic of technology integration in education for two major reasons. A second-order M-A, in general, as pointed out by Cooper and Koenka (2012), represents a limited means for addressing the host of peripheral questions, those that only can be settled in a primary M-A, where coding decisions are made by the meta-analyst based on detailed descriptions of various study characteristics supposedly provided by the authors of primary research, and the synthesis is conducted at the more granular level of the individual effect sizes. As a result, Tamim et al. (2011) could not examine a number of substantive and demographic moderator variables and thus provided insufficient texture or nuance to the overall results.

Another challenge that could not be fully met by this second-order M-A is rapidly changing educational landscape that tends to include more new technological tools and applications introduced to instructional practices in different amounts, combinations and under varying circumstances so that the classical comparison type of “technology versus no technology” (covered by so many M-As summarized in Tamim et al. 2011) is no longer the predominant classroom reality. Relatively recently, but gradually more and more prevalent, “technology versus technology” (more versus less or/and different kinds of)

type of educational settings (and subsequently type of comparison in empirical research) has become a more reasonable and more pressing question in modern education. The need to address and overcome (at least, partly) both these issues hence motivated the effort by Schmid et al. (2014) to perform a large-scale primary M-A of technology integration in postsecondary education.

Large-Scale M-A for a More Nuanced Understanding – Schmid et al. (2014)

While primary sample-based research is intended to provide an inferential link between a sample under scrutiny and the population that it is presumed to represent, M-A makes this link more explicit by examining the effects of a multitude of primary studies that have attempted to address the same question. Inferential statistics and associated assessment of significance are unnecessary because a M-A investigates the entire population of primary studies with like characteristics and conducted within a specified timeframe. In this sense, M-A looks at the “big picture,” or the characteristics of the phenomenon in terms of the entire body of primary studies that have examined it (including inspection of their specific characteristics – that is, study features, potential consistent influence of which on the magnitude of the effect size are assessed through moderator variable analysis).

The Schmid et al. (2014) M-A reported the overall weighted average effects of technology use on achievement and attitude outcomes and explored a fairly large set of moderator variables. Educational technology was broadly understood in terms of the earlier definition by Ross et al. (2010) as a “. . . variety of modalities, tools, and strategies for learning, [whose] effectiveness, therefore, depends on how well [they] help teachers and students achieve the desired instructional goals” (p. 19). Recognizing the limitations of the *technology versus no technology hypothesis* (i.e., comparisons between technology-enhanced and technology-free classrooms), Schmid et al. (2014) divided the entire collection of included studies into those with no technology in the

control condition and those with technology in the treatment condition and some technology in the control condition. To facilitate navigation through the review, here is a brief summary of major terms and definitions used in the M-A, followed by a set of inclusion/exclusion criteria and the key aspects of the review methodology (for the complete description of the methodology, please see Schmid et al. 2014).

Terms and Definitions

Educational technology is understood here according to Ross et al. (2010), as quoted previously. The *degree of technology use* was the primary determinant for assigning groups to either the experimental or the control condition. This distinction is important because it specifies the valence (positive/negative) of the effect size. Two types of studies were found, those that (similar to the research question of the second-order meta-analysis presented earlier) contained no technology in the control condition and those that contained some technology in the control condition. In the former class of studies, the assignment of the experimental and control group designation was clear. In the latter case, the differential use of technology in the two conditions was rated. The condition containing the “highest degree of technology use” (or more technology-saturated) was designated the treatment condition and the alternative condition served as its control. There were three possible interpretations of higher degree of technology use. The experimental group was considered: a) to contain the longest or most frequent exposure to technology tools; b) to contain more advanced technology (i.e., enabling more functions); and/or c) to employ a larger number of technology tools.

There were the following major purposes of technology use identified and analyzed in the reviewed studies:

- 1) To promote communication and/or to facilitate the exchange of information. This category includes technology that enables a higher level of interaction between individuals (i.e., two-way communications among learners and between learners and the teacher).

- 2) To provide cognitive support for learners. This category encompasses various technologies that enable, facilitate, and support learning by providing cognitive tools (e.g., concept maps, simulations, wikis, different forms of elaborate feedback, spreadsheets).
- 3) To facilitate information search and retrieval. This type of technology is intended to enable and/or facilitate access to additional information (e.g., web links, search engines, electronic databases).
- 4) To enable or enhance content presentation (e.g., Microsoft PowerPoint presentations, graphical visualizations, computer tutorials with limited interactive features).

When more than one purpose was identified, codes indicating multiple purposes were created (e.g., cognitive support plus presentational support). Achievement outcomes included various objective measures of academic performance (e.g., examination/test scores), but not self-evaluation. A wide spectrum of moderator variables were coded and analyzed: methodological (e.g., research design), instructional (e.g., purpose of technology use, pedagogical approach), demographic (e.g., subject matter), and publication (e.g., date, source).

Inclusion/Exclusion Criteria and Review Procedure

Studies under review that were included had to have the following characteristics: (1) be published no earlier than 1990; (2) be publicly available (or archived); (3) address the impact of computer technology on student achievement and/or attitudes; (4) contain at least one between-group comparison, where one group fits the definition of the experimental condition and the other group fits the definition of the control condition, using the criterion of the degree of technology use (higher versus lower); (5) be conducted in a formal post-secondary educational setting; (6) represent classroom or blended instructional environments, but not distance education; and (7) contain sufficient statistical information for effect size extraction when the latter is methodologically attributable to the effect of technology use and not to the influence of other factors.

Failure to meet any of these criteria led to the exclusion of the study with the reason(s) for rejection documented for further reporting. Two researchers working independently rated the studies, first at the abstract level, then at the full text level, on a scale from 1 (definite exclusion) to 5 (definite inclusion). All disagreements were discussed until they were resolved, inviting a third opinion when necessary, and initial agreement rates were calculated as Cohen's Kappa (κ) and as Pearson's r (where appropriate). Similarly, two researchers participated in all other data extraction procedures (i.e., effect size extraction and study feature coding).

Literature Search Strategies and Data Sources

Extensive literature searches (as outlined in detail in the original publication) were designed to identify and retrieve primary empirical studies relevant to the major research questions. Key terms used in search strategies, with some variations to account for specific retrieval sources, included ("technolog*," "comput*," "web-based instruction," "online," "Internet," "blended learning," "hybrid course*," "simulation," "electronic," "multimedia" OR "PDAs" etc.) AND ("college*," "university," "higher education," "postsecondary," "continuing education," OR "adult learn*") AND ("learn*," "achievement*," "attitude*," "satisfaction," "perception*," OR "motivation," etc.) AND excluding "distance education" or "distance learning" in the subject field.

The following databases were among the sources examined: ERIC (WebSpurs), ABI InformGlobal (ProQuest), Academic Search Premier (EBSCO), CBCA Education (ProQuest), Communication Abstracts (CSA), EdLib, Education Abstracts (WilsonLine), Education: A SAGE Full-text Collection, Francis (CSA), Medline (PubMed), ProQuest Digital Dissertations & Theses, PsycINFO (EBSCO), Australian Policy Online, British Education Index, and Social Science Information Gateway.

In addition, Google Internet searches were performed to help identify gray literature, including a search for conference proceedings. Review entries and previous M-As were used for branching, and the tables of contents of major

journals in the field of educational technology (e.g., *Educational Technology Research & Development*) were manually searched.

Effect Size Calculation and Synthesis

A *d*-type standardized mean difference effect size was used as the common metric (i.e., Cohen’s *d*), and then was transformed into Hedges’s *g* metric (Hedges and Olkin 1985) to provide necessary correction for small sample sizes. The random effects model (Borenstein et al. 2010) was the main analytical approach for this M-A. A mixed effects model was used to test the difference in levels of moderator variables. In a mixed analysis, average effect sizes for categories of the moderator are calculated using a random effects model. The variance component *Q*-Between is calculated across categories using a fixed effect model (Borenstein et al. 2010). All analyses, including sensitivity and publication bias analysis, were performed in *Comprehensive Meta-Analysis*™ 2.2.048 (Borenstein et al. 2008).

Results of Schmid et al. (2014) Meta-analysis
Out of an initial pool of 11,957 study abstracts, 674 primary studies were retained for analysis, yielding 879 independent achievement effect sizes after pre-experimental designs and studies with obvious methodological confounds removed. The overall random-model results of the Schmid et al. (2014) study are shown in Table 2. The produced weighted average effect size of 0.27 was significantly greater than zero. The collection of effects is significantly heterogeneous, based on findings from the fixed model where heterogeneity is tested in terms of the magnitude of *Q*_{Total} (variability). An effect size of

0.27 is considered small and represents a difference of 0.27*sd* between the mean of the treatment condition and the control condition, amounting to about an 11% difference. These results suggest that technology-supported instruction is advantageous compared to either non-use or limited use, but that this advantage is relatively modest.

The collection of achievement outcomes was divided into two subcollections, according to the amount of technology use in the control condition; these were “no technology” in the control condition ($\bar{g} = 0.25, k = 479, p < 0.01$) and “some technology” (though necessarily a lower degree of its use than in the treatment condition) in the control condition ($\bar{g} = 0.31, k = 400, p < 0.01$). Random effects multiple meta-regression analysis was run on each subcollection revealing three significant predictors (subject matter, degree of difference in technology use between the treatment and the control, and pedagogical uses or major function of technology). The set of predictors for each subcollection was both significant and homogeneous. Differences were found among the levels of all three moderators, but particularly among varieties of cognitive support applications. These findings are presented in greater detail later.

In summary, the Schmid et al. M-A was intended to (1) overcome some of the limitations of the previous reviews, including lower level of detailed information about individual primary studies in Tamim et al. (2011); (2) provide the most comprehensive first-order M-A of technology use in post-secondary classroom education; (3) encompass studies with “no technology in the control condition” and studies with “various degrees of technology in each condition”; and (4) look at the pedagogical use of a broad range of educational technologies and other important instructional moderator variables. Based on its major outcomes, several follow-up M-As were designed and implemented.

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses, Table 2 Overall weighted average effect size (random effects model)

Population estimates	<i>k</i>	$\bar{g}$	<i>SE</i>	Lower 95th	Upper 95th
Final collection	879	0.27*	0.02	0.24	0.31
^a Heterogeneity analysis	$Q_T = 3,183.10$ ($df = 878$), $p < 0.001$, $I^2 = 72.42$				

* $p < 0.01$

^aBased on the fixed effect model for $k = 879$

Examining the Details: Three Follow-Up Meta-analyses

A set of subsequent M-As addressed several additional questions, judged to be of high importance.

More specifically, the effects of various purposes of technology use (with the focus on cognitive support for learning), technology use in blended learning, instructional settings (interaction treatments) designed specifically to enable student collaborative work, and various pedagogical approaches to teacher education were investigated. Following is a brief rationale for each of these follow-ups.

Major Purpose of Technology Use

As educational technology advanced beyond media whose primary role was to deliver content to students (e.g., instructional television, multimedia applications, computer-assisted instruction), the following question arose in the theoretical and practical literature: “How can computers be used to support student cognition, without directly instructing them?” Jonassen (1995) addresses the practical issue, but Cobb (1997) provides a possible answer to the theoretical question. He argues that the most compelling role of computing in learning is its ability to afford “cognitive efficiencies” to students. In most, if not all, learning situations there is shared cognition among the learner, the task itself, and the tools that the learner uses in the process. Computer-based cognitive tools, he argued, could be designed and implemented to fulfill one of these roles. His rationale was that the more the learners can distribute cognition “outside of their heads,” the more the cognition that can be devoted to the process of learning new material. Therefore, one purpose of the Schmid et al. review was to explore whether and to what extent cognitive tools promote student achievement in learning environments involving technology, compared to other roles that computers might assume (e.g., presentation, search and retrieval, communication).

The Effects of Blended Learning

There is a growing literature of studies investigating blended learning, an instructional approach that involves a combination of elements of face-to-face and online instruction. It is sometimes argued that blended learning is the “best of both worlds” because it is a marriage of the best elements of the two practices, although it is still

arguable what these “best elements” are and how exactly they fit together. To date, there have only been a limited number of M-As devoted to blended learning (e.g., Means et al. 2013; Bernard et al. 2014, reported here; Spanjers et al. 2015).

In the Means et al. (2013) M-A, blended learning conditions were found to significantly outperform fully face-to-face classroom instruction ($\bar{g} = 0.35$, $k = 23$, $p = 0.001$). Several moderator variables were significant: 1) blended learning outperformed self-study; 2) collaborative learning and teacher-directed expository instruction significantly outperformed self-study; 3) in computer-mediated communications with instructor and among students, the asynchronous mode only was more effective than in combination with the synchronous mode; and 4) undergraduate students benefited more from blended learning than graduate students.

In the Spanjers et al. (2015) study, the overall effect size favored blended learning ($\bar{g} = 0.34$, $k = 24$, $p < 0.05$) for achievement based on objective effectiveness outcomes and ($\bar{g} = 0.34$, $k = 11$, $p < 0.05$) for achievement based on subjective effectiveness outcomes. These results closely mirror the Means et al. (2013) results. The presence or absence of quizzes appeared to differentiate the overall result in terms of objective effectiveness.

The Bernard et al. (2014) study, an offshoot of Schmid et al. (2014), addressed the following research questions: What is the impact of blended learning (i.e., courses that combine face-to-face and online learning) on the achievement of higher education students? How do various pedagogical factors (e.g., the amount of time spent online and the purpose of technology use) and course demographics (e.g., subject matter) moderate the overall average effect size? These findings appear in a later section.

Designed Interaction Treatments

Institutions of higher education provide students with the opportunity to interact with each other both inside and outside the classroom. Three major forms of interaction are important for effective learning, extrapolated from the distance education literature (e.g., Anderson 2003; Moore

1989). *Student–student* interaction refers to interaction among individual students or among students working in small groups. *Student–teacher* interaction traditionally focused on, but is not limited to, classroom-based dialogue between students and the instructor. Finally, *student–content* interaction refers to students interacting with the subject matter under study to construct meaning, relating it to personal knowledge, and applying it to problem-solving. Meta-analytical findings support the overall positive influence of the three types of interaction on learning outcomes with specific emphasis on student–student interactions (Bernard et al. 2009). Naturally, all three of these forms can occur in higher education classrooms without technology, but it was the intention of this study to investigate student–student interaction, supported by technology, in conditions that were specifically designed to support collaborative learning. Thus, the research question became, “Are *designed interaction treatments* (i.e., intentionally implemented collaborative instructional conditions that are meant to increase student learning) more effective than *contextual interaction treatments* (i.e., learning setups that contain conditions for student–student interaction to occur, but are not intentionally designed to create collaborative learning environments in technology-enhanced classroom instruction in higher education)?” This question is important because it emphasizes the use of instructional design to facilitate the potentially positive effects of technology use in higher education classrooms Borokhovski et al. 2013) in general, including preservice teacher training.

Technology Use in Teacher Education

Another follow-up of Schmid et al. (2014) focuses on the subset of studies that specifically addressed technology use in educational and teacher training programs. The main objective was to further explore the impact of technology use in this specific context in an attempt to determine what aspects of teaching practices set education apart from STEM (Science, Technology, Engineering, and Mathematics) and non-STEM disciplines. Moreover, it aimed to investigate the nature of the most effective pedagogical frameworks

supporting successful technology integration. The focus was on how technology was used by educational professionals to achieve educational goals.

While it is impossible to review all pedagogical frameworks available to instructors, it seemed appropriate to focus on student-centered instructional strategies. It is argued that the learner-centered approach supports learning by emphasizing the student’s role in the instructional environment, thus shifting the focus from knowledge transmission to the actual learning process (e.g., Laurillard 2002). Regardless of technology integration, general teaching strategies that are aligned with the student-centered philosophy include cooperative and collaborative learning (Bruffee 1993; Johnson and Johnson 2008); problem-based learning (Jonassen et al. 2003); and the provision of elaborate feedback (Hattie and Timperley 2007).

The Follow-Up Meta-analyses

Major Purpose of Technology Use

Study results become differentiated when effect sizes are divided by pedagogical application of technology. The results from Schmid et al. (2014) indicate that technology that is used to support student cognition outperforms all other categories, but especially presentational support (Table 3). This effect is interpreted as a difference primarily between “technology used by students” (for content understanding) and “technology used by teachers” (for content delivery). Other functions, such as support for communication and a mixture of cognitive and presentational support, fall in between these two.

Blended Learning

The effects of blended learning (i.e., partly in class and partly online) were derived from the Schmid et al. (2014) database and analyzed and reported in Bernard et al. (2014). As evident from Table 4, the random-effects weighted average effect size ($\bar{g} = 0.334$, $k = 117$) is larger than the overall average effect of technology use in the original M-A, and is in line with the findings from the other M-As of blended learning (Means et al.

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses, Table 3 Instructional moderator variable analysis: Major function of technology use

Levels of Technology Use	<i>k</i>	$\bar{g}$	Lower 95th	Upper 95th	Q_{Between}
Cognitive Support (CS)	186	0.36	0.28	0.44	
Presentational Support (PS)	113	0.15	0.07	0.23	
Communication Support	27	0.24	0.12	0.35	
Mixture (CS plus PS)	485	0.25	0.21	0.30	
Between Groups, $df = 3$	13.28, $p = 0.004$				
Contrast:	Cog. Supp. vs. Presentational Supp., $z = 5.14$, $p < 0.0001$				

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses, Table 4 Weighted average effects for blended learning

Analytical models	<i>k</i>	$\bar{g}$	<i>SE</i>	Lower 95th	Upper 95th
Random effect model	117	0.334*	0.04	0.26	0.41
Fixed effect model	117	0.316**	0.02	0.28	0.36
Heterogeneity	$Q_{\text{total}} = 372.91$, $df = 116$, $p < 0.001$		I^2 -squared = 68.89%		$\tau^2 = 0.11$

* $z = 8.62$, $p < 0.001$; ** $z = 15.68$, $p < 0.001$

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses, Table 5 Mixed effects analysis of the degree of student–student interaction

Levels	<i>k</i>	$\bar{g}$	<i>SE</i>	Lower 95th	Upper 95th	Q_{Between}
Equal in control and experimental groups	703	0.29	0.02	0.25	0.33	
Control group higher	127	0.16	0.04	0.07	0.24	
Experimental group higher	48	0.34	0.07	0.20	0.48	
Between groups, $df = 2$					8.93, $p = 0.012$	

** $p < 0.01$

2013; Spanjers et al. 2015). Apparently, there is an advantage that accrues from balancing face-to-face instruction with online learning outside of class. The mechanisms of this effect have not been determined, so one of the challenges of educational technology research of the future will be to tease out the effects of variables such as amount of time devoted to each pattern of instruction, the most effective learning strategies, and the teacher’s role in the online portion of blended learning.

Interaction Treatments

Interaction treatments were defined by Bernard et al. (2009) as instructional setups in distance education that are intended to facilitate and promote interaction among students, between students and teachers, and between students and the content. This definition was used to code studies

in the Schmid et al. (2014) study in classroom settings. Table 5 shows the results of this basic analysis. Conditions where interactions were greater in the treatment group, compared to the control condition, produced results that were significantly higher than the rest of the comparisons, especially those in which the control group was characterized as having more potential for interactions among learners. As expected, when the two conditions were roughly the same (i.e., $\bar{g} = 0.29$, $k = 703$), the outcome was not significantly different from the former condition (i.e., $\bar{g} = 0.34$ versus 0.29).

When the interaction treatments are divided further by the presence or absence of design intention, the results strongly support *designed interaction treatments* over *contextual interaction treatments* (Table 6). It appears that merely providing the means for student–student interaction

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses, Table 6 Mixed effects analysis of designed and contextual interaction treatments

Levels	<i>k</i>	$\bar{g}$	<i>SE</i>	Lower 95th	Upper 95th	<i>Q</i> _{Between}
Designed treatments	31	0.46*	0.01	0.32	0.60	
Contextual treatments	17	0.07	0.02	-0.22	0.37	
Between groups, <i>df</i> = 1	5.41, <i>p</i> = 0.02					

**p* < 0.01

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses, Table 7 Moderator variable analysis for subject matter (STEM vs. Non-STEM vs. Education)

Levels of subject matter	<i>k</i> ^a	$\bar{g}$	Lower 95th	Upper 95th	<i>Q</i> _{Between}
STEM subjects	356	0.28	0.23	0.33	
Non-STEM subjects	454	0.25	0.20	0.30	
Teacher education	66	0.45	0.32	0.58	
Between groups, <i>df</i> = 2	7.78, <i>p</i> = 0.02				

^aThree cases of unidentified subject matter or mixture of several subject matters were removed from the analysis (*k* = 876)

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses, Table 8 Moderator variable analysis: Type of pedagogical (conceptual) framework

Framework	<i>k</i>	$\bar{g}$	Lower 95th	Upper 95th	<i>Q</i> _{Between}
Collaborative learning	6	0.06	- 0.24	0.35	
Feedback strategies	11	0.75	0.38	1.12	
Information processing	5	0.26	- 0.17	0.70	
Multimedia theory	8	0.46	- 0.10	1.01	
Problem-based learning	9	0.56	0.16	0.96	
Between groups, <i>df</i> = 4	9.71, <i>p</i> = 0.046				

is not enough as a pedagogical strategy. Some form of instructional design is needed (e.g., collaborative learning, reciprocal teaching).

Technology Use in Education Courses

In this final section, the effects of educational technology across subject areas are investigated. Because of contemporary interest in teacher education (i.e., teaching future teachers), these studies are broken out from other Non-STEM content areas and their average effect size compared with that of STEM (i.e., science, technology, engineering, mathematics) and the remaining Non-STEM subject areas. The results, shown in Table 7, revealed nearly equal average effects for STEM and Non-STEM education, but a noticeable difference between these areas and technology used in teacher education.

To investigate further what might account for such a high average effect for teacher education, studies were further classified according to the underlying pedagogical frameworks for using technology in these studies (Table 8). Only studies from the education sub-group, where there was a clear indication of a particular pedagogical approach to instruction and associated use of technology, were included. This reduces the number of effect sizes from *k* = 66 to *k* = 39. Although this number after the split somewhat limits the power of subsequent analyses, using technology to provide feedback to students resulted in an unusually high average effect size of $\bar{g}$ = 0.75 (*k* = 11). Two other instructional approaches to technology use were also prominent: multimedia theory and problem-based learning were each around $\bar{g}$ = 0.50. Notably, the use of technology

to support collaborative learning (i.e., group projects) was very low (less than $\bar{g} = 0.10$) and not significantly greater than zero. These findings suggest the need for further exploration of the range of technology uses in education, as well as in allied areas such as nursing education.

The subcollection of studies that focused on STEM subject matters was further explored for effects of several moderator variables (Tamim et al. 2015a). This study found no significant differences across categories of STEM subject areas: $Q_{\text{Between}} = 2.80$, $df = 3$, $p = 0.42$, with the highest magnitude of the effect for mathematics ($\bar{g} = 0.35$, $k = 69$) and the lowest for engineering ($\bar{g} = 0.23$, $k = 41$). In other words, the effect of technology use was quite consistent within the STEM domain, which indirectly supports treating these fields of study as a coherent conglomerate of related subject areas, at least in postsecondary education. At the same time, previously described findings in favor of technological tools used for cognitive support for learning received its additional confirmation specifically for STEM education: $Q_{\text{Between}} = 7.06$, $df = 1$, $p = 0.008$.

What Next

The series of M-As presented encompassed various aspects of research in the field of technology integration in education, which was broadly understood as all types of computer-based instructional practices. Lately, the attention of researchers and practitioners is gradually shifting toward identifying and closely examining more specific tools and applications that may present some kind of a break-through and fulfill a longstanding promise of seriously changing educational practices and outcomes. Two particularly prominent patterns could be named. One deals with more and more sophisticated technologies, such as interactive simulations and serious games that target learning and expertise development in specific subject matters, like science, engineering, and health education. Another turns more in the direction of multifunctional mobile devices that are reasonably affordable, so that they could be ubiquitously available to students and used for a multitude of learning goals. Both directions can give rise to related research, including systematic

reviews and M-As. See, for example, research summaries on: simulations in STEM education (e.g., D'Angelo et al. 2013), digital serious games (e.g., Clark et al. 2016; Wouters and van Oostendorp 2013, where the latter emphasized not the games per se, but the value of instructional support in digital gaming environments), and ubiquitous laptop instructional interventions (e.g., Zheng et al. 2016).

The next section presents an overview of a recent systematic review and an M-A of tablet use in educational contexts (e.g., iPad, iPod, PC [personal computer or Android-based] tablets), an overview of large-scale government initiatives of tablet use in education around the globe (Tamim et al. 2015b) followed by a systematic review of research investigating the impact of tablets on students' performance (Tamim et al. 2015c), which was further updated with the focus on comparative quantitative research (Tamim et al. 2017).

Mobile Technology

At the present time, there is an abundance of institutional, regional, and national initiatives that make use of mobile devices in school-based elementary and secondary (i.e., K-12) and higher education contexts. This is evident in the large-scale government-led initiatives to distribute tablet devices to students in K-12 schooling sectors in eleven countries around the world (Tamim et al., 2015). Limited attention has been given to best practices or lessons learned from research, and there is a need to ensure that empirical evidence is synthesized and shared in a timely fashion. A systematic review of research studies published since 2010 and addressing the impact of tablets' use on students' achievement has been completed. In light of the relative recency of tablet introduction into classrooms and the potential shortage of related experimental research, the systematic review covered both quantitative and qualitative research studies. The review included the following:

A-. *Meta-analysis* aiming at synthesizing quantitative research with the objective of

answering two complementary but distinct research questions:

1. What is the impact of tablets on students' achievement when compared with treatments that do not utilize tablets for instructional purposes?
2. What is the impact of tablets when utilized with the support of a pedagogical framework on students' achievement in comparison to their use in an absence of a pedagogical underpinning?

B-. *Qualitative Research Review* with the objective of reviewing qualitative research to gain an understanding of students' perceptions about the most prominent aspects of effective tablet use for teaching and learning.

A focused search strategy was designed with the research being reviewed for inclusion upon meeting the following inclusion criteria:

- Be published in English 2010 onward.
- Feature educational use of tablets (laptops and smartphones excluded).
- Allow for comparison between two instructional conditions with tablets in one or both groups.
- Describe primary empirical research of all designs except for "one group pre-to-post-test" preexperimental design (the latter were considered for possible inclusion in the qualitative research review).
- Be conducted in formal educational settings addressing general student populations.
- Report measures of student achievement and contain sufficient statistical information to enable effect size extraction.

A targeted search strategy was developed to encompass a broad variety of sources including ERIC; Education Full Text (Wilson); Education Source; EdITLib; ProQuest Dissertations & Theses databases, as well as Internet manual searches and branching. After removal of duplicates, a total of more than 2,000 unique records were retrieved at the abstract level. Two independent researchers reviewed approximately 45.5% of the collection and met to resolve disagreements. After

establishing reliability agreement rate of 92.4% (Cohen's $\kappa = 0.85$), the researchers completed the review of the second half of abstracts separately. The same approach was taken for the review of retained 443 full-text documents with the agreement rate of 93.3% (Cohen's $\kappa = 0.87$). Full-text review resulted in a final included set of 118 primary studies that fell into the following categories:

- 69 quantitative research studies used in the meta-analysis that resulted in a total of 86 unique effect sizes.
- 7 quantitative research studies with one group pre-to-post-test design that were used in the qualitative literature review since they were judged to be informative of tablet-based instructional interventions.
- 42 qualitative research studies (case studies, observations, broad-scope surveys, interviews, etc.) were used in the qualitative literature review.

Analysis revealed significant low-to-moderate average effect sizes of tablet use in comparison with no-tablet contexts. However, it was also clear that decisions with respect whether or not to introduced tablets to the instructional practice were made for a variety of reasons – from just following a fashionable trend to the intend to enable carefully designed pedagogical interventions that take into account and rely on functional richness of "smart" mobile technology. The latter usually took form of teaching and learning we called "technology plus" (pedagogy-driven) instructional conditions, where the use of technology is determined by instructional design and/or teachers' understanding of its capacity to fulfill relevant learning objectives. Findings indicated that those pedagogically sound tablet-enhanced instructions resulted in even stronger effect-sizes when compared to what could be described as convenient tablet use. Table 9 shows average weighted effect sizes for student achievement outcomes for both fixed and random models, with associated statistics. Although there is no direct comparison possible between the tablets/no-tablets and the tablets+/tablets, results are in line with

Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses, Table 9 Overall achievements effects for both research questions

	<i>k</i>	<i>g</i> ⁺	Lower 95th	Upper 95th
<i>Question 1: Tablets vs. no tablets</i>				
Random effects model	65	0.222	0.12	0.32
Fixed effect model	65	0.194	0.15	0.24
Heterogeneity (fixed effect model)	$Q_T = 245.05$	$df = 64$	$p < 0.001$	$I^2 = 73.88$
<i>Question 2: Tablets with enhancements vs. unmodified tablet use</i>				
Random effects model	21	0.784	0.50	0.52
Fixed effect model	21	0.635	1.07	0.75
Heterogeneity (fixed effect model)	$Q_T = 106.36$	$df = 20$	$p < 0.001$	$I^2 = 81.20$

previous research findings (e.g., Schmid et al. 2014) and are suggestive that specifically designed technology-based instructional interventions have higher potential for learning than modern technology per se.

Qualitative Research Synthesis

The qualitative research review included 49 studies with the objective of offering an in-depth understanding of effective use of tablets as perceived by the students. The qualitative studies reflected students’ overall positive perceptions of tablet use in educational contexts, which seem to be stronger within more student-active contexts. The narrow scope of the projects and/or limited information provided in the entries did not allow for critical analysis and reflection. Nevertheless, substantive study features, a brief overview of the treatment, and overall findings for each of the studies were extracted. Some of the more commonly cited advantages by students included the following:

- Improving organizational and note-taking skills.
- Enhancing ability to express themselves and their understanding in creative ways.
- Supporting their independence and communication skills.
- Increasing accessibility to resources while supporting complex visualization of concepts.
- Improving their literacy and mathematics skills.

As for the most commonly cited challenges, they were as follows:

- Technical issues and needed expertise.
- Distracting nature of the device and plethora of Apps.
- Pressing need for teachers’ professional development to enable them to integrate the use of the device for the enhancement of the teaching and learning process.

Discussion

The current entry provides a review of findings from a substantive body of M-As and systematic reviews completed by researchers in the area of educational technology. The main research questions that were addressed include the following:

1. What is the overall weighted average effect size and variability for studies that investigate the impact of the instructional uses of technology on student achievement outcomes?
2. Is there a difference in average effect sizes for achievement outcomes associated with major purposes of technology use?
3. What is the weighted average effect size and variability for studies that investigate the impact of the instructional uses of technology in so-called blended education?
4. Is there a difference in the weighted average effect sizes for achievement outcomes associated with designed versus contextual interaction treatments?
5. What is the effectiveness of instructional technology in teacher training dependent on a particular pedagogical approach/framework?

6. What is the overall effect of using tablet technology in education in comparison with technology-free instructional environments?
7. Is there added value of enhancing tablet-based learning in comparison with the random use of mobile technology in classrooms?

Overall Findings

Both second order all-encompassing M-A (Tamim et al. 2011) and large-scale primary M-A of technology integration in postsecondary education (Schmid et al. 2014) were coherent in the major message they delivered that educational technology does have a positive, though rather modest (low or low-to-moderate) effect on students' learning outcome across subject areas and grade levels. The magnitude of the overall weighted average effect sizes in these two M-As was quite compatible ($\bar{g} = 0.35$ and $\bar{g} = 0.27$ – for the former and the latter, respectively, also parallel to the findings of the validation study: $\bar{g} = 0.33$), both significantly heterogeneous.

Cognitive Versus Presentational Support Tools

Based on the analyses of the purposeful use of technology, we see where Clark's original assertions about the passive nature of technology may have arisen. Technologies prior to the 1980s and well into the 1990s were indeed passive because their primary purpose was to convey content to students, either through the actions of teachers' use of presentational software or as a consequence of computer-aided instruction (CAI). Feedback, of course, was present in these stand-alone technologies, but it often amounted to simply providing the "right answer" without elaboration (Azevedo and Bernard 1995). Not until the advent of personal computers, and especially software and online tools that "work with" the student in the learning process, have changes in technology use that educators could not have envisaged prior to 1980 been seen, when much of Clark's work was done.

The overall message emerging from these data is that learning is best supported when the student learns through meaningful activities via technological tools that provide cognitive support during

the learning process. However, we are a long way from understanding more specifically how to design effective cognitive support tools (which could be of two very distinct broad categories: those enabling distributed cognition – e.g., worksheets, spellcheckers; and those supporting understanding and deep learning – e.g., simulations) and when precisely to integrate them into instructional practices. Research programs to help bridge knowledge gaps in these areas are considered of value.

Blended Learning in Higher Education

For the longest time, there were two primary venues for learning in higher education – classroom instruction (with or without technology support) and distance education, which has evolved into online learning. While there is considerable evidence that technology that is used to support classroom instruction is beneficial, it is a requirement when students and teachers are in separate locations, often working asynchronously (in the correspondence education era, when the post office provided a transfer technology). It is now possible to marry these two environments, providing students with some time in classrooms and the rest – online out of classrooms. The results of studies of these so-called blended or hybrid learning experiences are encouraging (Means et al. 2013; Bernard et al. 2014; Spanjers et al. 2015), but it is still not possible to predict with confidence which variables are most influential (e.g., instructional strategy applied in each context) and which are trivial (e.g., time spent in each pattern), or how to design effective blended learning given the myriad of circumstances that can arise under various conditions. Research work in this domain could well be of value to university students.

Collaborative Interaction Treatments

A M-A has identified the link between the intentioned and designed use of technology in higher education classrooms and the provision of technology without such explicit intention, though generally high heterogeneity of meta-analytical findings indicates that, dependent on a particular educational context, observed effects might grow or diminish and suggests caution in

their overall interpretations. These results provide educators with specific guidance about what works and does not work in the domain of education, especially as it relates to technology-based student–student interaction. This part of the M-A reaffirms the effectiveness of computer-supported collaborative learning (CSCL) from the perspective of technology use and the design of instruction that aims to support and amplify interaction. Once again, pedagogy and specific instructional design take precedence over the contextual communicative benefits of modern educational technology.

Technology Use in Teacher Education

Current analyses have moved one step beyond responding to the general question of whether technology works or not. Findings have confirmed previous results and provided meaningful insights with regard to specific pedagogical approaches that are successful in improving student performance. The general analyses are in line with the findings of the overall M-A (Tamim et al. 2014), indicating the importance of cognitive support tools for successful learning. In addition, results further suggest that moderate intensity and complexity of technology use works better than oversaturation.

A current M-A provides some input regarding pedagogical strategies that work more effectively for educating preservice teachers. Particularly speaking, provision of adequate and specific feedback to students in technology-supported environments greatly increases the impact of technology use on student performance. The resulting average effect size of 0.75 translates into a 27-percentile gain for average students in the experimental group compared to those in the control group. The gains are significant and the implications are clear. Instructors need to incorporate feedback in their technology-enhanced instruction. Another pedagogical approach for successful use of technology in educational contexts is problem-based learning (PBL), where the average effect size of 0.56 indicates a 21-percentile gain in student performance.

Finally, one of the most interesting pieces of evidence in one study pertains to the importance

of training in successful technology integration in postsecondary education. This is in striking contrast to the belief that the newer generation of students is so technologically savvy that they do not need additional formal training.

Tablets for Teaching and Learning

The presented M-A addressing tablet use in educational contexts provided findings that indicate a moderate-strength average effect size of tablet uses on students' outcome measures. Moreover, higher effect sizes have been achieved when the devices are used in student-centered contexts. Of important relevance to academics and instructional designers is the implication that the impact of tablets on students' performance is amplified when it is used with a particular pedagogical framework such as collaborative work and project/problem based learning.

As for the qualitative literature review, tablets seem to be garnering positive perceptions about their effectiveness within educational contexts. When specifically questioned, the effectiveness of the devices was noted to be higher for particular tasks and when used with a student-centered pedagogical approach.

Concluding Remarks

In conclusion, three particular outcomes of this review of M-As that are important for research and practice are as follows:

- Technology alone, no matter how advanced, sophisticated, and fashionable, hardly works beyond its “novelty effect” in the absence of the other operative consideration – “educational.” Well-thought through instructional design and effective pedagogical strategies (e.g., interaction treatments designed for collaborative work, elaborate feedback) provide the substantial value-added that transforms whichever technology is adopted – including tablets – into technological tools that are advantageous for teaching and learning.
- Blended learning, which can combine the best qualities of face-to-face and online instruction, appears to offer a viable teaching/learning option for applying educational technology to

achieve its maximum benefits for learning. Nevertheless, this outcome is still to be further substantiated by both primary research and meta-analytical reviews. Beyond the practical advantages of blended learning, it is necessary to know how to combine the best of the face-to-face world with the best of the online world.

- In-time technology training for teachers and students is of high relevance and importance for the successful integration of technology within educational contexts. The belief that simply providing teachers and learners with the latest technology will transform the educational process has been shown by a range of researchers to be a misconception. For teachers, mere technical training does not transfer to pedagogically appropriate utilization of technology for teaching and learning. As for students, their familiarity and ubiquitous use of technology in their daily lives does not imply that they will be able to successfully use it to attain expected learning outcomes.

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Qualitative Methods, Lesson for Information Systems Researchers

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Introduction

Research methods are regarded as tools or vehicles that are used in a research study to achieve its objectives. Patten and Newhart (2018) consider research methods to be building blocks of scientific inquiry that facilitates the acquisition of systematic knowledge. Research methods can thus be seen as being comprehensive and complex in their different applications in various subject areas (Walliman 2015). According to Davies and Hughes (2014), there are two main types of research methods, namely qualitative and quantitative research. However, Griensven et al. (2014) argue that the two types can be combined and also considered to be a type of research method called “mixed method.”

Even though this study is not about comparing both research methods, it is necessary to point out some of the differences with the purpose of putting the methods into perspectives. Qualitative methods differ in many ways from quantitative methods. However, the rigor required for

analyzing quantitative data is also required in qualitative methods, but with greater challenges because even though the analysis is rigorously conducted, it is done without the help of any mathematical rules (Hammarberg et al. 2016).

Quantitative methods are of an objective nature, based on numerical data that is measured or statistically analyzed (Bambale 2014). According to Clarke and Collier (2015), quantitative data is collected through a systematic approach with its focus being to answer questions of how and how much about a specific phenomenon. Biswas and Muthukkumarasamy (2017) state that in quantitative research methods, there is an emphasis on identifying theories, hypotheses, and then testing and measuring them. On the other hand, qualitative methods give emphasis to the individual’s perspectives, personal opinions, and experiences (Cope 2014). Differing from opinions about quantitative methods, Hammarberg et al. (2016) assert that qualitative methods are of a subjective nature, thus focusing on an understanding of the individual’s viewpoint about a phenomenon being studied. According to Beail and Williams (2014: 85), qualitative methods “form the foundation of many areas of theory and evidence in the physical and social sciences.” When applied strictly and carefully, qualitative methods also form the scientific foundation of critical subjects (Palinkas 2014). According to Hammarberg et al. (2016), there are some subject areas where it is critical to get an understanding of what the phenomena mean to

each individual or group rather than the counting and measuring of statistical numbers. This kind of understanding is achieved in many subject areas only through the use of qualitative methods which involve a clear understanding of why things happen the way they do (Palinkas 2014; Hammarberg et al. 2016).

Despite the endless number of benefits that the qualitative methods present, there is evidence of its many challenges. Haahr et al. (2014) highlight ethics as one of the challenges that is often experienced when using qualitative methods such as conducting interviews, particularly when close relatives and colleagues are the participants. This type of challenge can be attributed to the fact that the researchers interact directly and personally with the participants, sometimes offering their own meaning (Sanjari et al. 2014). From a different perspective, Saunders et al. (2015) assert that it is very challenging to anonymize qualitative data and yet still maintain the integrity of data, especially in delicate contexts.

Even though many challenges have been highlighted in the literature about qualitative methods in IS research, problems linger on, making some postgraduate students avoid qualitative methods and opting for an alternative (Marshall et al. 2013). This is a critical problem in that some students' avoidance of the methods is not based on merit or suitability, which sometimes makes their research more complex which may affect the outcome as well. Many scholars acknowledge how difficult it is to reduce the complexities in the IS field by using quantitative research (Goldkuhl 2012). Thus, the objective of this study was to examine the challenges of qualitative methods in IS research, and through a model propose a solution.

For the purposes of flow and clarity, it is necessary to explain how this entry is structured. The entry consists of four main sections. The entry is introduced in the first section where the objective is also presented. Guided by the objective, existing literature relating to the subject are explored in the second section. The complexities that are often experienced in information systems (IS) research are discussed in the third section.

Thereafter, a conclusion is reached, completing the section.

Existing Literature

Information systems and technologies (IS/IT) are used to automate and manipulate various processes and operations for individuals and organizational purposes (Stair and Reynolds 2013), which can assist an organization toward achieving its strategic mission. With the use of IS/IT for various purposes, employees in an organization are classified as end-users (Iyamu and Kekwaletswe 2010), making both people and IS/IT equally important in an environment. Callon (1986) explains from asymmetric position that both humans and nonhumans are equal within a network. Our inevitable assertion leans toward the fact that IS/IT artifacts neither exists by themselves nor operate in a vacuum, without humans or their effects on human processes and activities (Iyamu and Shaanika 2018). Within this context, research has increasingly been carried out in the areas of IS/IT over the years, to evaluate, assess, and manage the development, implementation, and post-implementation activities in organizations (Erickson 2012). Also, owing to IS/IT connectedness with human efforts, qualitative methods have popularly been selected in IS research, as explained by Walsham (2018).

Some time ago, Myers and Avison (2002) suggest that qualitative research methods originate from the social science field, with the objective of enabling a researcher to study social and cultural phenomena. Today, the position has not been disputed. Reference has been made here to the origin of the methods so as to draw attention to and connect the facts with some of the challenges that are currently experienced by many postgraduate students. The qualitative research method is often employed in IS studies to interrogate the influence and impact that human perceptions and nontechnical aspects have on organizations (Iyamu 2015). Without undue controversy, Kornbluh (2015) explains that the aim of many researchers that apply qualitative methods is to develop an understanding of the

phenomenon by examining the ways in which participants experience, perceive, and make sense of their lives.

Increasingly, many researchers have applied qualitative methods in their studies to address various problems and objectives, such as the impact of organizational structure on the implementation of IS (Indeje and Zheng 2010) and determining the critical success factors of people that influence the successful implementation of IS/IT (Aziz and Salleh 2011). Kornbluh (2015) conducted a study to establish the challenges of trustworthiness in qualitative research. The study tried to establish consistency in selecting trustworthy respondents who would not be biased in the data provided owing to their positions. Another challenge with qualitative methods is providing justification for some of its techniques, such as sampling (Robinson 2014). The respondents, number of respondents, and the number of interview questions are referred to as sample size, which can be a challenge for some researchers (Marshall et al. 2013). From the results of their research, they have found that there is little rigor in justifying sample size and no consistency applied when determining sample sizes for studies where the case study approach or grounded theory is followed.

The use of qualitative methods has been a challenge for many IS researchers over the years. Dickson-Swift et al. (2007) claim that some challenges are unique to qualitative research. Marshall et al. (2013) suggest that qualitative research is time-consuming and mentally exhaustive when compared to other forms of research. Qualitative research lacks guidelines on the perspectives of data collection and data analysis, and the processes are subjected to the discretion of the researcher. Yin (2009) argues that since the processes are not structured and consistent, it puts a lot of pressure on the intellect, ego, and emotions of the researcher. Owing to a lack of standardized guidelines, based on their know-how, researchers employ methods and techniques to achieve the objectives of their studies as they deem fit. Puebla and Davidson (2012) postulate that there is no right way to approach qualitative research, but there are different ways that qualitative research

can be approached in order to achieve its objective.

Since qualitative research methods are primarily concerned with an understanding of people (Myers and Avison 2002), researchers are sometimes entrusted with private and sensitive information or perceptions of the participant's views, which could be a challenge to some researchers, thus making it necessary, but difficult, to manage the information. Subsequently, it is expected from the researcher to treat the collected data with confidentiality, which may be regarded as too much of an effort to accomplish by some researchers. Dickson-Swift et al. (2007) explain that researchers have the responsibility of facilitating the management of participants' disclosure of confidential information in the process of their studies. However, this can be achieved by establishing trust between the researcher and the participant (Mutudi and Iyamu 2018).

Even though Booth and Booth (1994) also propose that researchers need to develop a level of trust so that participants are comfortable about sharing their stories, it remains a challenge to do so. However, in order to establish trust with the participants in a short time, some researchers disclose private information about themselves to establish comfort and trust with the participants. Dickson-Swift et al. (2007) observe that the researcher tries to be innovative about gaining trust. Results from their study suggest that some researchers admit that self-disclosure was a conscious effort in order to enhance the relationship between them and the participants.

Qualitative researchers are faced with the challenge of being too subjective during data collection and data analysis. Their subjectivism can distort the data collected during transcription and analysis, if not managed properly. In an effort to mitigate this challenge, "member checks" are conducted (Kornbluh 2015). Member checks are the processes whereby a researcher validates findings with participants in order to ensure that the participant's intended meanings reflect accordingly, which allows for the detection of personal biases of the researcher (Marshall and Rossman 2010) and this process of validation can be time-consuming and tedious.

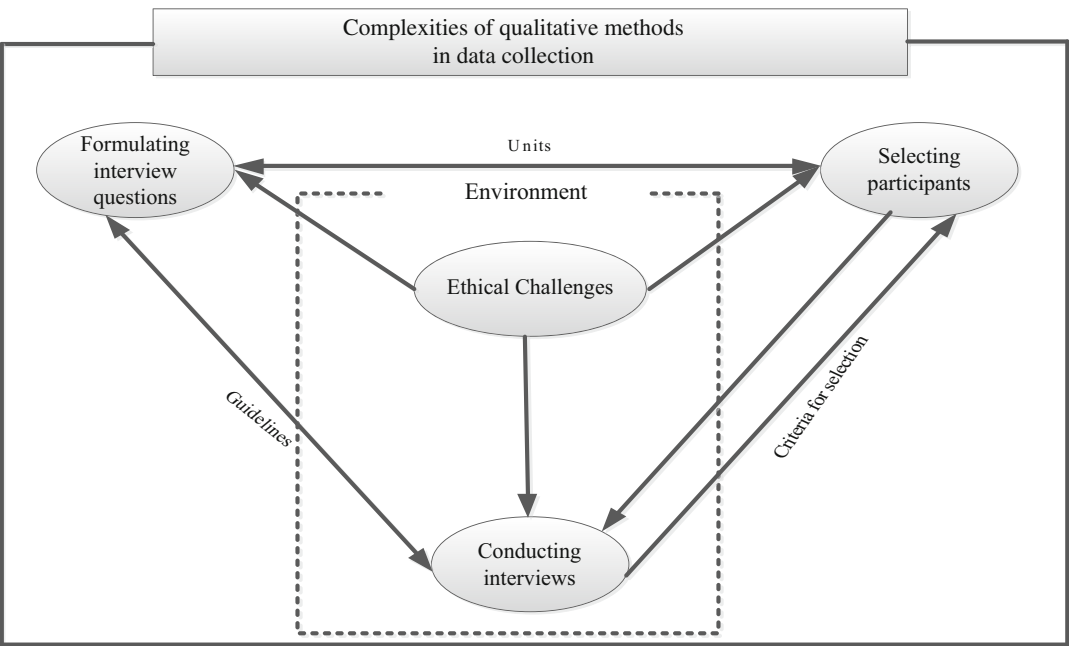
Understanding the Complexities

The analysis of the existing literature helps us to form and gain a different understanding. From the analysis, four critical challenges were found, which included formulating interview questions, conducting an interview, and selecting respondents and ethical challenges. The challenges are diagrammatically represented as shown in Fig. 1. By means of Fig. 1, the connection between the challenges is illustrated, to indicate how they influence one other in the application of the methods.

Formulating Interview Questions

The interview is one of the most popular techniques that is used to collect data from the perspective of qualitative research methods (Mikkonen et al. 2015; Firth et al. 2016). It is well documented that data were the most critical aspect of research primarily because they influence the quality of the research positively or negatively (Rimando et al. 2015). Thus, it is crucial to formulate appropriate interview

questions that are used in collecting data. This is one of the reasons why this requires attention as aspiring researchers and postgraduate students continue to encounter challenges in qualitative research during the data-collection process (Iyamu and Shaanika 2018). The challenges begin with the formulation of interview questions. These can be attributed to the fact that some aspiring researchers and postgraduate students tend to be too academic when phrasing the interview questions. As a result, some of the questions come across as a test or examination of knowledge, which becomes difficult for some participants to answer (Montoya 2016). This reduces the interviewee’s participation in conversation, which affects the quality of the data, as the richness of the data is influenced by the ability of the researcher to interrogate the subject by getting interviewees to share more of their views and opinions (Iyamu and Shaanika 2018). Therefore, experience is required from the researcher in order to formulate questions in an easy and understandable way for the participants to embrace (Rimando et al. 2015).



Qualitative Methods, Lesson for Information Systems Researchers, Fig. 1 Complexities of qualitative methods in data collection

The type of interview question that is formulated influences the kind of interviewees that are selected to partake in the study. As shown in Fig. 1, it is necessary to have a basic idea of the unit of analysis in formulating the questions (Montoya 2016). According to De Vaus (2013), units of analysis are categories of sources of information about the phenomena being studied. Based on the formulated questions and the pre-determined units, the researcher selects the participants that have knowledge about the subject. Presumably, they are able to provide data that are rich enough to accomplish the objectives of the study (Curry et al. 2009). For example, when investigating the impact of IS on users in an organization, the interview questions should be formulated in sets that focus on different units. The first unit attempts to address the deployment of IS and the second, the perceptions of the users who are from the business units, respectively.

Selecting Participants

The type of participants that are selected in a qualitative research is critically important. However, it is often a difficult task for many post-graduates in that qualitative research rejects a random selection of participants (Gentles et al. 2015). Qualitative researchers experience different challenges at each stage of the methodology, for example, challenges experienced during data collection are different from the challenges experienced in data analysis. Before starting with data collection, a researcher needs to plan and have an idea of the kind of participants who should take part in the research. This will be respondents that are part of the research problem and give insight and clarity on the subject matter. Primarily, this is because it is nearly impossible, from random sampling, to determine the people who are knowledgeable about the subject (Marshall et al. 2013), which also makes the approach more difficult to justify. A researcher needs to select respondents that are knowledgeable about the subject matter, thus having confidence that the interaction will result in rich data that can be used to fulfill the objective of the research. Not selecting the most appropriate respondents for an interview can lead to collection of poor data that can impact on the

objective of the research negatively. Along the same line of argument, Curry et al. (2009: 1445) claim that “the aim is to identify information-rich participants who have certain characteristics, detailed knowledge, or direct experience relevant to the phenomenon of interest.”

It is important that participants in empirical studies are selected for a specific purpose. According to Palinkas et al. (2015), the participants of a study are selected based on predefined criteria by the researcher. Thus, as shown in Fig. 1, there is a two-way communication between the participants selected and the researcher conducting the actual interview in that they both influence one other. Such communication requires some degree of experience to avoid “silent” intimidation, which sometimes can happen between some aspiring researchers and interviewees. From another viewpoint, the relationship between the researcher and interviewee allows the latter party to freely share his or her experience in the deepest form to the extent of sometimes answering some questions even before they are posed. At this point, the responsibility and ability lies with the researcher to have the right attitude and open mind in managing the process to his or her advantage (Curry et al. 2009).

Conducting Interviews

There are different types of techniques including a questionnaire that could possibly be used to collect data in a qualitative research. The in-depth interview is one of the more popular techniques that can be used in collecting data from a qualitative method perspective, a technique which Curry et al. (2009) define as typically one-to-one interaction between a researcher and a respondent. The in-depth interview allows the researcher to probe for more clarity if needed. According to Iyamu (2015), qualitative research is interrogative and the researcher is allowed to get clarification on questions such as who, why, what, when, how, and where. However, probing is not simple to execute, because knowing precisely when to probe for more clarity is a challenge for some researchers, which is a skill a researcher acquires with time and experience. Yin (2009) posits that an experienced researcher will be able to take

advantage of unexpected opportunities during data collection. These opportunities, which could add value to the objective of the research, can easily be missed by an aspiring qualitative researcher.

Within the postgraduate community, there is a narrative that conducting an interview is complex and requires highly skilled researchers. Curry et al. (2009) suggest that the ability to use probes and follow-up questions in order to provoke more responses requires a skillful understanding of the process. Curry et al. (2009) add that it is important for researchers not to create a situation that would not discourage respondents from freely expressing themselves. Most importantly, this is to mitigate against a situation that could discourage up-and-coming researchers who wish to engage with respondents or to undertake an in-depth interview at some stage in their careers.

A code of conduct is another factor that influences the use of the interview technique for data collection. For various reasons, interviews are guided by a code of ethics which differs from one environment to another. According to Senter et al. (2018), a code of ethics is a set of rules and principles that serve as a guide for ethical behavior within a particular environment or organization. However, each environment has a specific code of ethics which is influenced by factors such as culture and goals (TeRiele and Brooks 2013). It becomes challenging for some postgraduate students and aspiring researchers in their first few experiences to deal with ethical issues in the different environments where they are to conduct the interview.

Ethical Challenges

Dealing with the challenges discussed above is not an easy exercise in many cases, especially when there are ethical issues involved. Sanjari et al. (2014) state that ethical challenges are one of the major challenges when using qualitative methods. According to Saunders et al. (2015), the temptation to be unethical under difficult situations is greater in qualitative research. For example, in a situation where it is difficult to get individuals to participate in a study, a researcher can be tempted to unethically convince individuals to participate in his or her research.

According to TeRiele and Brooks (2013), paying individuals to participate in research where payment is not a custom of the participants, may be seen as an inducement, which can therefore be considered unethical. There are other ethical challenges, such as inconsistency and a lack of transparency. Gentles et al. (2015) argue that, irrespective of the reason, it is unethical to dismiss an individual after his or her offer to participate in the study voluntarily has been accepted. Such action may be considered to be morally offensive for some individuals in certain environments. Therefore, the researchers may find themselves in an ethical dilemma that is very difficult to solve.

Sometimes, a researcher may have a preconceived outcome in mind. This preconception could develop during the literature review or from exposure to the subject matter. Consequently, researchers can become desperate if their preconceived outcomes are not met through the interviews that are conducted. Researchers can thus be tempted to act unethically in order to fulfill their preconceived outcome. According to Myers and Avison (2002), the researcher's preconception affects the collection of data, in that the researcher may pose questions that are aimed largely at addressing what they wish to find out.

Ethical challenges are found at every stage of research. As demonstrated in Fig. 1, ethics is the factor that influences the way interviews will be formulated, the way the participants will be selected and how the interview will be conducted.

Conclusion

This entry will be of particular interest and benefit to both postgraduate students and aspiring researchers from two main academic standpoints, namely theoretical and practical. From a theoretical standpoint, this entry can guide researchers to avoid pitfalls which others have fallen into, in the process of collecting qualitative data for their studies. An understanding of this entry through the discussion of its complexities can make the use of qualitative methods look easy in practice. This entry can also be used as teaching and learning material by academics, thus contributing to

the body of knowledge through its addition to existing literature. Even though so much work has been done on qualitative methods, this entry brings a different dimension based on its specific focus on challenges that develop into complexities, which could be considered as a theoretical contribution in the field of IS.

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Qualitative Research

- [Digital Storytelling in Teaching and Research](#)

Quantitative Synthesis of Research

- [Promises and Prospects of Educational Technology, Evidence from Systematic Reviews and Meta-analyses](#)

R

Rationales for Information Technology in Schools, Historical Perspective

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Synonyms

Classroom; History; Orchestration; Pedagogy; School; Technology-enhanced learning

Introduction

Computers have had a presence in school classrooms for 50 years now, and digital technology has advanced considerably over this time. How have the ideas behind their use to aid teaching and learning developed over the same time period?

This entry will focus on the reasons and intentions for the use of technology as one element of the learning environment in schools. It will discuss the key issues of pedagogy which relate to the organization of classroom learning and examine the variation in pedagogical rationales for IT during the past 25 years.

Pedagogy and IT

Approaches to teaching have often been characterized as a dichotomy: the transmission of

knowledge or the facilitation of learning. However, Alexander (2008) rejects this simplistic categorization and suggests that teaching can be viewed as:

- Transmission
- Initiation
- Negotiation
- Facilitation
- Acceleration
- Technology

The key variables in these perspectives on teaching practice are organization, discourse, and meaning. These are based on primordial values concerning human relationships: individualism, community, and collectivism. They vary over time and across different cultures according to beliefs “about the extent to which knowledge is open or bounded, provisional or contestable; about how ideas should be handled; about the kinds of authority that teachers and curricula embody and the extent to which they can be questioned; about how individuals and groups should relate to each other; about the balance of individual autonomy and collective responsibility; about what counts as successful learning; and about what it means to be educated” (p. 39). Such fundamental issues concerning teaching will have profound effects on intentions for IT in the classroom. For instance, the variation in the ratio of structured talk to writing by learners in different pedagogical traditions (Alexander 2008) may be

of particular significance for the use of technology.

Pedagogy is not just about the teacher, of course, and there are related variations in views of learning: children may be seen as imitators, recipients, thinkers, and knowledgeable (Bruner 1996). Again, teachers' views of their students will strongly influence their deployment of IT resources and the role IT plays in their relationship with learners. The intentions for the use of technology are likely to be quite different in a classroom culture based on interaction between learners compared with one based on individual study and interaction only with the teacher.

Two key concepts developed by Shulman (1986) have been used in many studies of teacher thinking: pedagogical knowledge and pedagogical reasoning. Pedagogical knowledge comprises a number of interrelated aspects, including general pedagogical knowledge (the principles a teacher uses in managing learning, based on their beliefs and values) and pedagogical content knowledge (how the teacher represents subject-specific ideas for students to learn). This framework thus acknowledges the variation of pedagogy according to the subject taught as well as according to general views of teaching and learning. It has been developed further to incorporate IT into teacher thinking, and Mishra and Koehler (2006) devised the TPACK framework to represent the complex influences that technology can have on each of the aspects of teacher knowledge.

Pedagogical reasoning represents the process of transforming knowledge of subject content into knowledge for teaching. It includes the planning and preparation that take place in advance of lessons and the dynamic rethinking of activity which takes place in the classroom. Webb and Cox (2004) extended Shulman's original ideas to produce a framework for pedagogical practices relating to IT use which involves the key idea of "affordance" (Gibson 1979). This framework takes account of teachers' beliefs and is more sensitive than TPACK to the decisions and actions taken by teachers and learners when using IT and other media as aids to learning.

The terms affordance and constraint have been used widely to analyze how factors in the

environment influence activity (see, for instance, Kennewell 2001 and Webb 2005). They are valuable tools for the analysis of educational activity, particularly where students carry out actions in pursuing certain goals which are generally set by the teacher. Learners have options concerning their actions in pursuit of these goals and make decisions based on the affordances and constraints offered by the learning environment. While some of the features of the activity setting will be fixed, many others can be manipulated, and term orchestration has also been used widely over recent years to characterize the manipulation of the environment's affordances for learning (Prieto et al. 2011).

At a general level, "orchestration refers to how a teacher manages, in real time, multi-layered activities in a multi-constraints context" (Dillenbourg 2013). More precisely, it concerns the purposeful arrangement of affordances and constraints for students' actions during a task in order to bring about learning from their actions (Kennewell 2001). It is not only the teacher who can orchestrate activity; learners themselves can manage their environment to some extent. Orchestration can range from teacher intervention during collaborative activity using tablets in a primary school mathematics lesson (Prieto et al. 2011) to students seeking help from teaching assistants in a university Physics class (Dillenbourg 2013).

Five key elements comprise the orchestration of learning: design/planning, regulation/management, adaptation/flexibility/intervention, and awareness/assessment (Prieto et al. 2011). In a formal setting, whether in a classroom or online, a teacher will typically:

- Design a task and plan the resources to be available to students.
- Discuss the concepts and techniques relevant to the task.
- Give procedural instructions.
- Explain outcome expectations.
- Monitor student activity and intervene with individuals or groups: adding or changing resources, instructions, or expectations; answering and asking questions, providing prompts and explanations.

- Evaluate outcomes, assess learning, and provide feedback.

Teachers will aim to align the affordances of the environment to the intended learning objectives. Students may also manipulate the affordances and constraints to help achieve the task goal, particularly by using peers to help explain ideas, clarify instructions, and locate resources. This may inhibit the intended learning, however – for example – if one student just copies the work of another or focuses merely on completing the task in the simplest manner (Kennewell et al. 2008).

An orchestration perspective provides a means of analyzing the role of digital technology in learning and how it changes with increasing technological advance and maturity of implementation. In characterizing how learners' actions are facilitated together with how their actions may be restricted, it offers a more sophisticated framework for studying the way in which learning is managed than the simple idea of balance of control. Furthermore, it provides valuable insight into teachers' intentions for the use of IT.

Analysis of Rationales for IT

In the light of the variations in pedagogical belief and practice, it is not surprising that the role of technology in teaching and learning has been seen differently at different times and in different cultures. Early in the development of digital technology, two important classifications of IT use were posited:

1. Instructional, revelatory, conjectural, emancipatory – Kemmis et al. (1977)
2. Tutor, tool, tutee – Taylor (1980)

These ways of analyzing of IT's pedagogical role are similar; the second has the virtue of simplicity and has perhaps had the more influence on subsequent research and practice. They both match the pedagogical classifications to some extent; tutor/instructional corresponds to teaching as transmission and children as

imitators/recipients; tool/emancipatory corresponds to teaching as facilitation and children as knowledgeable; tutee/conjectural corresponds to teaching as negotiation and learners as thinkers; and revelatory corresponds to teaching as initiation.

More generally, three broad forms of rationale have been employed since the early days of IT in schools, and each can be characterized by its relation to orchestration.

1. *Replacement*: IT is intended to adopt some or all of the roles traditionally carried out by the teacher and students. This may involve the technology being programmed to orchestrate the learning environment (e.g., managing the allocation of tasks for the learner, providing repetitive practice with feedback) or merely being one resource available to the teacher and/or student as part of the environment which the teacher orchestrates (e.g., engagement of learners through a visual or interactive display).
2. *Augmentation*: IT is intended to adopt new roles which traditionally the teacher and students have not carried out. This requires new forms of orchestration by the teacher and/or learners (e.g., simulation).
3. *Transformation*: IT is intended to facilitate a fundamental change in the process of teaching and learning, particularly enabling learning as participation in knowledge development rather than reception of knowledge. This shifts the orchestration of the environment to the students (e.g., word processing for drafting/redrafting, modelling for testing ideas).

The ways in which these broad rationales have underpinned practice at different times can be traced in the contributions to the World Conference on Computers in Education (WCCE), for example. The themes selected for these conferences over the past 25 years reveal changing intentions:

- Freedom for learners (WCCE 1995 – Liberating the Learner), suggesting a reduction in orchestration by the teacher

- Collaboration/connectivity between learners (WCCE 2001, *Networking the Learner*; 2013, *Learning While We Are Connected*), suggesting the facilitating of orchestration by learners
- Effectiveness of learning environment (WCCE 2005, *What works?*; 2009, *For a Better World*), suggesting a focus on outcomes rather than pedagogy
- Involvement of all in learning (WCCE 2017 – *Tomorrow's Learning: Involving Everyone*) – confirming the shift to learner orchestration

Most of these reflect a rationale of transformation. In order to explore these intentions more closely in relation to orchestration, however, it is necessary to examine contributions more closely (Kennewell 2017).

The first WCCE to have a theme was in 1995, when there was clearly a desire to use digital technology to help give students more influence over learning situations. The theme of “liberating the learner” was interpreted quite cautiously, but the idea that the teachers’ control could and would diminish in the digital environment ran right through the contributions analyzed. Consequently most papers were concerned with how this more student-centered scenario might be implemented in terms of technological design. The focus on orchestration in the analysis has brought out a variety of ways in which the management of learning might be shared among different participants: teachers, students, and the technology itself. The key issue for implementing technological assistance in any setting is not what the balance of control should be but what contribution each of the participants can best make to the processes involved in orchestration. It did not seem in 1995 that technology was at the stage of making a large, active contribution to either design/planning, monitoring/intervention, or assessment/feedback, and for most contributors, it remained a tool and resource for the human agents involved.

A number of developments since 1995 have made a substantial impact on teaching and learning. These include:

- Learning management systems: these can be accessed anytime and anywhere, but despite the name, they do not actually orchestrate learning themselves but rather provide a structure and features which support management of resources by teachers but impose significant constraints on learners (Bennett 2011). While these have been embedded widely in higher education institutions, their adoption in schools has been much less than was anticipated a few years ago.
- Interactive whiteboards: these also provide many features which can afford and constrain classroom activity but have been largely used by teachers to facilitate their traditional approaches to orchestrating resources and are valued for their effects on engaging learners (see, e.g., Kennewell et al. 2008). These devices have been very widely adopted in schools but have had less influence in higher education.
- Web2 and social media: structures such as blogs, wikis, news broadcasting, and social networking have all been appropriated widely for educational purposes; they have affordances for interaction over distance and time but pose considerable challenges for distributing the orchestration between teachers and students (ASHE 2014), and perhaps because of this, they do not yet seem to have been adopted widely in schools.
- Mobile learning and 1:1 classroom devices: again, they clearly offer affordances for action which are flexible in place and time and also for individualized learning. The distribution of orchestration is again a challenge, and although in many institutions it is the norm for each student to have a computer in the classroom, their use in schools is often tightly constrained by the teacher, and students are not allowed to use their own devices because of potential distractions (Weigend 2017).
- Gamification: this approach represents a particular mode of orchestration in which the activity setting takes the form of a game in some way. The constraints are managed by the computer according to the rules of the “game,” and the affordances for action are

orchestrated largely by the learners. Perhaps for this reason, game-based learning is seen as particularly motivating for students (Caponetto et al. 2014). As the active role of the teacher may be quite small, it is particularly suitable for use outside the classroom.

In each of these cases, it seems that the degree of adoption of the technology in different sectors is directly correlated with the fit between the form of orchestration supported by the technology and the traditional pedagogy of the teacher. In other words, IT is used when it helps the teacher to do what they already do. The process of pedagogical reasoning has been adapted, but it does not seem that most teachers have developed their knowledge and beliefs to incorporate IT.

The most recent WCCE in 2017 adopted the theme “Tomorrow’s Learning: Involving Everyone.” Involvement seems to require more than just access to teaching and resources; it suggests that our aim for all should be active participation in learning.

A number of contributors to WCCE 2017 addressed this issue. Some identified the nature of the task as an important factor in motivating learning. The creation of a worthwhile product was seen as particularly significant, particularly if this presented a challenge to learners, although such challenges must be seen as realistic targets by learners, and an alternative strategy involving finding, trying out, and reflecting/discussing is also effective. Digital technology can support game environments which engage learners actively with learning tasks within and beyond the classroom and increase students’ interest in the learning process itself rather than just the grades achieved. It can increase the “learnability” of topics by positioning students positively in relation to difficult concepts. While a digital learning environment may be designed for active learning or active participation, the affordances of the technology may not be sufficient on their own to sustain student engagement, and many learners need the support of the teacher or others, either in the classroom or online (Kolbaek and Nortvig 2017). For learners accustomed to using technology on the move, physical activity with mobile

devices outside the classroom also aids engagement in learning (Weigend 2017).

The idea of “freedom” had not entirely disappeared; for some contributors, choice was seen as an important factor in involvement of learners. Being able to select a theme of personal interest to work on was motivating for students, although there was some concern that students might only be motivated by themes in which they were personally interested. Freedom to use heuristic methods in problem-solving was supported by digital environments, a situation which is reminiscent of the vision for LOGO classrooms in the 1980s which had largely disappeared in 1995.

Conclusion

IT changes not just what is orchestrated but the nature and location of orchestration itself. The challenge of progressing from provision of access to teaching toward engagement and participation in learning can be informed by the analysis above. There is overwhelming evidence that digital technology motivates students to participate in activity; the difficulty comes in stimulating students to focus on learning from that activity. Teachers are generally adept at designing and preparing environments that offer affordances for all students in their charge. The first stage in the development of active participation involves being able to judge when digital technology can provide more or better affordances for learning. But IT environments provide affordances for many other actions, and in order to avoid distractions, students must first adopt the teacher’s intention, not just for task completion but for achieving the intended learning outcomes.

The second stage is for students themselves to learn to orchestrate affordances and constraints for learning: this is the essence of “intentional learning” (Bereiter and Scardamalia 1989). Effective learners do this already, but many students do not seek – or are prevented from using – prompts from peers, new resources, or even familiar tools. Digital technology can support this sharing of orchestration (see, e.g., Turner 1995) which dealt with this idea explicitly, but some learners will

need support from teachers or other people (Saito 2017).

In this entry, the changes in rationale for the use of IT in the classroom have been characterized in terms of teachers' pedagogical thinking and in particular their intentions for the orchestration of affordances in the classroom environment. This has shown that the developing affordances of IT may not be aligned with teachers' rationales which have their roots in pedagogical beliefs.

Where teaching is viewed as transmission or as technology, the potential of IT is not likely to be fully exploited. This has implications for policy-making, professional development, and resource provision in all parts of the world. A transformation rationale means a fundamental change in pedagogical perspective to teaching as negotiation or facilitation, which cannot be achieved merely by providing more or better IT.

Cross-References

- [Blended Learning](#)
- [Classroom Use, Blended Learning](#)
- [Collaborative Learning and Patterns of Practice](#)
- [Computer-Assisted Learning](#)
- [Game-Based Learning](#)
- [Gamification](#)
- [Mobile Computing and Mobile Learning](#)
- [Mobile Learning](#)
- [Modeling the Process of Information Technology Innovation in Education](#)
- [Online Teaching, Emotions, and Emoticons in Computer-Mediated Communication](#)
- [Situative Perspective and Determinants of Technology Acceptance in Educational Technology](#)
- [Social Media and Networks as Digital Instruction and Learning Platforms](#)
- [Technology Enhanced Learning](#)

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Receptacle

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Restructuring Teachers' Knowledge for Teaching with Technologies with Online Professional Development

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Synonyms

[Inservice teacher professional development](#); [Online professional development](#); [Teacher knowledge development](#); [Technological teaching knowledge](#)

Introduction

A significant challenge for today's teachers is that they actively engage in teaching their content with today's technologies. This challenge recognizes that, with the rapid pace of new and more robust technological learning tools, teachers are at a

disadvantage because they have not learned with these technologies. Now, they must envision how these new technologies support learning of their content as well as which pedagogical strategies are effective in engaging students in learning with the technologies. They must identify, orchestrate, and manage different strategies and learning tasks in their content areas in order to effectively support students with twenty-first century critical learning skills. In other words, today's teachers must continue learning in order to guide students in learning for their tomorrow. Teacher educators thus are challenged to respond to this important question: How can today's teachers engage in learning about the technologies and about teaching with the technologies while they are actively teaching in their classrooms?

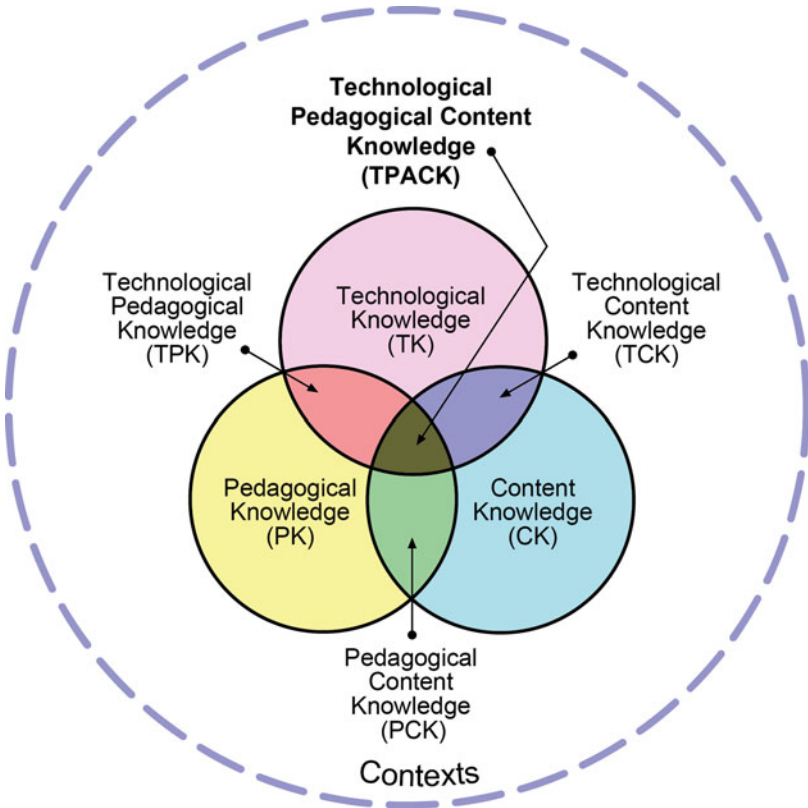
Teachers' knowledge for tomorrow is far more than just an understanding of the subject matter content. It ultimately necessitates a robust pedagogical knowledge along with knowledge for teaching with the vast array of technological

innovations. The task calls for what has been identified as Technological Pedagogical Content Knowledge (Angeli and Valanides 2005; Mishra and Koehler 2006; Niess 2005), otherwise referred to as TPACK (Thompson and Mishra 2007). TPACK as shown in Fig. 1 describes the transformation of teachers' knowledge at the center intersection of content knowledge, pedagogical knowledge, and technological knowledge to support teachers in the strategic thinking of when, where, and how to guide students' learning with technologies.

While the TPACK construct is recognized and supported by extensive research and scholarly work, teacher educators are faced with identifying appropriate professional in-service learning experiences to effectively reconstruct teachers' knowledge into a robust pedagogical understanding so that they understand and are able to guide students in collaborating and communicating as they engage in inquiry tasks using multiple technologies as learning tools. When determining

Restructuring Teachers' Knowledge for Teaching with Technologies with Online Professional Development,

Fig. 1 Representation of Technological Pedagogical Content Knowledge (TPACK) as teachers' transformed knowledge. (Reproduced by permission of the publisher, © 2012 by tpack.org)



appropriate instructional strategies for developing teachers' TPACK, Mishra and Koehler (2006) claim that:

There is no single technological solution that applies for every teacher, every course, or for every view of teaching. Quality teaching requires developing a nuanced understanding of the complex relationship, and using this understanding to develop appropriate, context-specific strategies and representations. (p. 1029)

Now, teacher professional development must be designed to guide teachers in reconstructing their knowledge, to engage in relearning, rethinking, and redefining teaching and learning as they know and learned it. Basically, they must confront their current conceptions to integrate technologies as learning tools in their content areas (Loughran 2002) to develop the reformed and reconstructed TPACK understandings.

An increasingly recognized educational setting for teachers' professional learning experiences is provided through online instructional avenues, providing increased access for many more teachers. Teacher educators must incorporate effective online learning experiences to reframe teachers' knowledge and this provision must happen today as the new technologies are evolving at an increasing rate. Teacher educators are, therefore, faced with multiple important questions as they consider designing new professional development instructional venues. What are the important features for an online learning trajectory for guiding teacher educators in redesigning their learning experiences? What online learning trajectories are not only useful for engaging teachers in knowledge-building communities but also provide them with an understanding of the pedagogical challenges for establishing these similar communities in their classrooms? How can teachers gain classroom-based learning experiences where they apply their learning about teaching with technologies? What structure might be used for an online learning trajectory for teacher education?

This case study examined a researcher-conjectured and empirically supported learning trajectory instructional approach to enhance in-service teachers' TPACK for teaching with a

technology new to them. The primary question for this study was: How might a TPACK learning trajectory support a blend of teachers' online communities of learners with practical teaching experiences so that they have the opportunity to apply their TPACK in ways that advance their knowledge toward a TPACK-of-practice?

Theoretical Framework

Reconstructing in-service teachers' knowledge to reflect the ideas described by TPACK requires systematic inquiries about teaching, learning, subject matter and curriculum, and schooling, much as that described in Cochran-Smith and Lytle's (2001) conception of "knowledge-of-practice" as a "transformed and expanded view of what 'practice' means" (p. 276). This conception assumes that knowledge is "socially constructed by teachers who work together and also by teachers and students as they mingle their previous experiences, their prior knowledge, their cultural and linguistic resources, and the textual resources and materials of the classroom" (p. 280). This conception of teacher learning necessitates incorporation as an inquiry community where reflection is a central component (Cochran-Smith and Lytle 2001; Loughran 2002; Schön 1983). The vision of TPACK can therefore be referred to as a *TPACK-of-practice*.

Borko (2004) describes a process for identifying high-quality teacher change programs, beginning with studies in a single site, exploring relationships between teachers as learners in a specific learning trajectory. Confrey and Maloney (2010) further describe a learning trajectory as a "researcher conjectured, empirically supported" description of an "ordered network of experiences" where students move from "informal ideas, through successive refinements of representation, articulation, and reflection, towards increasingly complex concepts over time" (Confrey and Maloney 2010, p. 968). For the learning trajectory in this study, the teacher is the student in the instruction designed to move from informal ideas about teaching with technology through successive refinements toward a

reconstructed knowledge for teaching with technology. Thus, through purposeful design, this experience models the instructional strategies for teaching with technologies.

The researcher-conjectured unit design was supported by an empirically supported online learning trajectory (Niess and Gillow-Wiles 2013). The trajectory identified key instructional strategies through a social metacognitive constructivist instructional framework that described the tools and processes for driving the content development in an online asynchronous, text-based learning professional development. The study then examined the teachers' advancement in their TPACK-of-practice resulting from their experiences in a course that blended their practical experiences with their online community interactions.

Tools

Two key tools were incorporated in the asynchronous, text-based, online experiences – (1) a community of learners and (2) reflection. Learners in online experiences typically are required to make sense of new information in isolation with only asynchronous avenues for making connections with other learners and the instructor. Thus, a community of learners is an essential tool that supports the learners in communicating and interacting through discussions about the tasks and ideas being presented. This tool establishes a social presence through the community such that it functions as a knowledge-building community.

Multiple researchers have indicated that such a social presence establishes community member participation and educational experiences that result in meaningful learning, open communication, and group cohesion (Garrison et al. 1999; Garrison and Cleveland-Innes 2005; Hill et al. 2009; Kinsel et al. 2005; Rourke et al. 1999; Swan and Shih 2005; Sung and Mayer 2012). Garrison and Cleveland-Innes (2005) have explained the importance of engaging learners in active roles in online environments for establishing an understanding as they made sense of the new information and ideas. The community of learners provided a dynamic integration

of the social, cognitive, and teaching presences toward higher order learning, where they also claimed “the reflective and collaborative properties of asynchronous, text-based online learning are well adapted to deep approaches to learning (i.e., cognitive presence)” (Garrison and Cleveland-Innes 2005, p. 145).

Reflection provided a second important tool for the online learning trajectory. Critical reflection has supported the cognitive presence throughout the online learning trajectory. Learner engagement in reflection was supported in multiple ways, such as having learners prepare content reflective essays as well as reflective essays on their community engagement and providing peer reviews or other learners' work. In this study, the teachers used a TPACK reflective tool for guiding reflections of their progress with four TPACK components (Niess 2005) and their emerging TPACK development levels (Niess 2013).

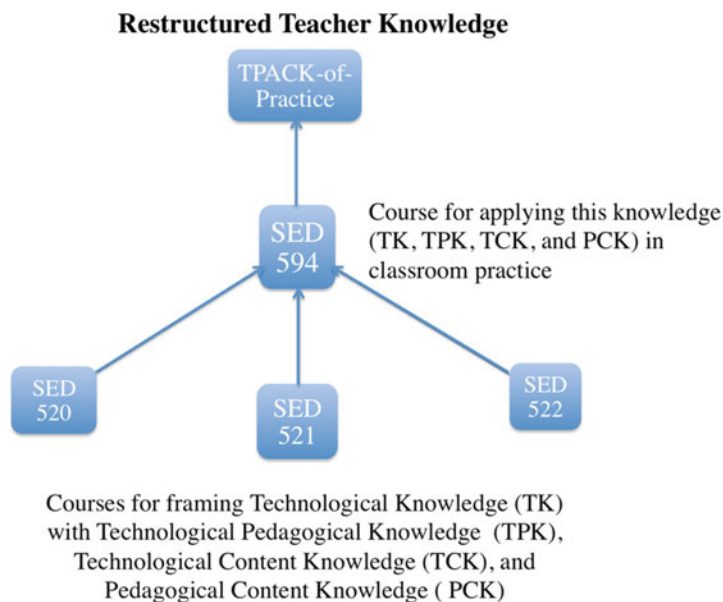
Processes

The second primary component of the online learning trajectory included the support of processes for using the tools for learning. Two processes were helpful in the online learning trajectory for engaging the social and cognitive presences in the social metacognitive constructivist framework: (1) shared/individual knowledge development and (2) inquiry. As the learners engaged in the community of learners' activities, they shared their understandings of how they interpreted the ideas. As the discussions evolved through their interactions, the learner's individual knowledge developed. In relying on the primary trajectory tools (community of learners and reflection), the learners moved between group and individual knowledge-building where they created understanding that more clearly reflected a world view with respect to the course (Dunlap and Lowenthal 2014; Rienties et al. 2013; Swan 2001). Thus, their individual knowledge expanded beyond that which they were able to develop independently.

Another key process with the knowledge-building communities was the use of inquiry-

Restructuring Teachers' Knowledge for Teaching with Technologies with Online Professional Development,

Fig. 2 Model for restructuring teachers' TPACK-of-practice



based activities to support the learners in opportunities and experiences where they were engaged in negotiating their understanding of the content. The inquiry process engaged participants in constructing their understandings, where they took ownership of their learning, starting with questions and exploration leading to investigating worthy questions, issues, problems, or ideas. They asked questions, gathered and analyzed information, generated solutions, made decisions, and justified their conclusions. The resulting actions interwove multiple technologies, instructional approaches, and content topics through multiple units. Throughout the process, the participants consistently engaged in thinking and reflecting about the dynamic interactions among content, pedagogy, and technology that emerged from the tasks in their online learning experiences (Roberts 2002; Wheatley 1992).

Online Master's Degree Program in Mathematics Education

The online Master's program in Mathematics Education concentrated on the development of the teachers' TPACK-of-practice for teaching mathematics with technologies. Four specific

courses emphasized developing the teachers' TPACK-of-practice (as shown in Fig. 2).

Three courses (SED 520, SED 521 and SED 522) merged the teachers' thinking about Technological Knowledge (TK) with Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Pedagogical Content Knowledge (PCK). SED 520 envisioned the use of multimedia technologies for twenty-first century mathematical literacy. This course engaged the teachers with key pedagogical tools and processes for learning with technologies with specific attention to learning through collaboration, reflection, inquiry, and shared/individual knowledge development. SED 521 considered digital image and video technologies for engaging students in higher order thinking in mathematics. Again, this course guided the teachers with similar pedagogical tools and processes as in SED 520 for learning with different technologies. SED 522 emphasized spreadsheets as algebraic reasoning tools. The emphasis was on solving mathematical problems using spreadsheet tools to design dynamic and dependable spreadsheets.

The fourth course, SED 594, blended online discussions with practical teaching experiences. Throughout this course, the teachers applied their accumulated knowledge as they designed,

implemented, analyzed, and reflected on their teaching of a technology-infused 5-day instructional unit in their mathematics classrooms. They gathered artifacts for their electronic portfolios for describing their instructional strategies and the tools and processes they used for guiding their students in learning with technologies. Their electronic portfolios demonstrated how they implemented collaboration, reflection, inquiry, and shared/individual knowledge development in their own classrooms as they integrated technologies for learning mathematics.

As they engaged in this practical experience, they used the online collaborative groups to discuss and explore different instructional strategies, tools, and processes for teaching with technologies. They cooperatively explored and examined new, reform-based instructional strategies – visible thinking, student discourse, grouping structures, and multiple representations for motivation and engagement. Toward the end of the course, the participants conducted peer reviews of others' electronic portfolios to improve the communication of the events and thinking.

The Study

This descriptive case study examined how practical teaching experiences blended with teacher-participants' inquiries through a community of learners influenced the participating teachers as they rethought, relearned, and redefined teaching of mathematics with multiple technologies. The course progression engaged them in inquiries about instructional strategies for teaching mathematics with technologies as they simultaneously engaged in systematic inquiry of teaching in their classrooms. The primary research question examined how and in what ways a practical experience of teaching a 5-day unit with technology combined with community collaboration in examining instructional strategies influenced the restructuring of their TPACK-of-practice. Nine (9) K-12 in-service teachers (eight females, one male; teaching elementary

(2), middle school (3), and high school (4)) agreed to participate in the study as they examined their teaching of mathematics with technology in their classrooms. All had taught more than 3 years, most between 4 and 8.

Data Sources and Evidence

Individual teacher case binders (Myers et al. 2003) combined their electronic portfolios, the online discussions from the community or learners' inquiries, and the final course reflective essays. Independent analysis of the case binders revealed patterns and themes in the discussions and reflections, capturing each teacher's progression and outcomes from the practical teaching experiences and the community collaborations. Each analysis documented the teacher-participants' knowledge progression with evidence of their TPACK-of-practice and thinking framed with respect to four TPACK components (Niess 2005) throughout the practical teaching experiences and tasks as well as the online collaborative discussions: (1) overarching conceptions about the purposes for incorporating technology in teaching mathematics; (2) knowledge of students' understandings, thinking, and learning in mathematics with technology; (3) knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics; (4) knowledge of instructional strategies and representations for teaching and learning mathematics with technologies. Collectively, each participant's TPACK-of-practice was described and confirmed. The completed case binders clarified the nine descriptive case analyses while also validating the cross case themes from the electronic portfolios, online discussions, and the final essays considering a primary research question: What is the impact of the teachers' experiences in the online course that blends the teachers' practical experiences with their online community discussions (orchestrated by the researcher-conjectured learning trajectory) on their TPACK-of-practice?

Study Results

Analysis of the nine K-12 mathematics teachers' blended online experiences resulted in a clear description of the development in their TPACK-of-practice. The teacher-participants' experiences and reflections described how their TPACK knowledge was influenced as a result of their practices and discussions. Two representative cases (using pseudonyms of Allysa and Barbara) highlight the patterns within the diversity of their classroom situations. These analyses demonstrated how the blended course, through their classroom artifacts, expressions, and reflections, influenced the teachers' developing knowledge for teaching mathematics with technologies and ultimately reconstructing their TPACK-of-practice.

Allysa

Allysa was motivated to implement and examine new and different instructional strategies from her typical instruction – working with graphing calculators and taking advantage of small group work. Prior to this experience, her primary instructional mode was teacher-centered but this teaching experience provided with the opportunity to test more the student-centered instructional strategies that she had been experiencing in her online courses. Through her video analyses of her teaching, she observed that having students working in groups provided opportunities for the students to share ideas; she noted how these opportunities enhanced the students' engagement and learning. "Through the video analysis and my own reflections, I felt I did witness students using discourse." Through the variety of opportunities for reflections in this blended online course, she concluded that she wanted to move to more student-centered strategies and she wanted technology to be part of that effort as noted in this comment:

The strategies of grouping, problem solving, questioning, and student discourse all allow the

learning environment to be centered on students who are actively engaged. . . I want to use more technology-centered activities. . . Technology must be integrated using instructional strategies; on its own, it is not an instructional strategy

The combination of the online discourse with other teacher-participants as they investigated and discussed the various instructional strategies allowed Allysa an opportunity to examine different instructional strategies when implementing the technology in her instruction. The blended experiences (discussion and teaching) supported her in recognizing and accepting the importance of student-centered strategies and group work.

Barbara

Trying new ideas, such as those in Allysa's case, was also seen in Barbara's case as she, too, wanted to go beyond the technologies to enhance her knowledge beyond those she had previously used with her students. Barbara used the blended course to integrate multiple technologies for teaching mathematics; in particular, she was interested in using technologies that supported communication, collaboration, and inquiry around the mathematical ideas. As she said, "Prior to this year, I have not had much experience with student-centered, hands-on, technology-rich, discovery learning strategies." Thus, in this experience, she added multiple data collection probes to engage students in gathering actual data that resulted in generating exponential, logarithmic, and logistic functions. She recognized that integrating real-time data collection with spreadsheets and Google Docs for analysis provided her with an opportunity to conduct a deeper analysis of her instruction as she incorporated multiple different instructional strategies as to what she normally did in her primarily direct instruction classroom strategies. Barbara was particularly interested in strategies that involved whole group and small group discussions, inquiry learning, and real-world applications while taking advantage of the basic features of the multiple technologies. In the

videos of her teaching, she saw how the students “were engaged in discovery learning, brainstorming, technology-enriched lessons, discussion, collaboration, and other strategies.” She viewed how her students interacted, shared ideas, and demonstrated their understandings. This recognition underscored the importance of “being a guide rather than the sole provider of information” as she had more typically done in her teaching. Her community of learners’ discussions supported the implementation of these multiple strategies for more student-directed instruction. In particular, she noted that when engaged in discourse, the students were more confident and comfortable communicating their ideas to the class or their small groups. “When they get stuck on a problem, they talk it out and only turn to me for help if they cannot come to a common agreement.” Through this process, she recognized that she “learned that they can do more student-centered activities with the right amount of support.” She closed with a promise for her future planning: “I will remember this as I plan other lessons.”

Cross Case Analysis

These two cases clearly showed the impact of the blended course through the teachers’ classroom actions as they integrated technologies as mathematics learning tools. The research question for this study focused on identifying how this blended course experience provided a reconstructed vision of the teachers’ TPACK-of-practice. In all nine cases, the teachers recognized the value of incorporating student-centered instruction, an instructional strategy that dominated their online discussions but had not previously dictated their classroom instruction. The electronic portfolios provided clear descriptions of the classrooms, with pictures of the classrooms and students in action along with presentations and analysis of varying levels of student work. The multiple reflections prior to, during, and following each lesson revealed multiple opportunities for the teachers to think about and learn from their technology-infused lessons. The online discussions

became sounding boards for ideas, helping the teachers to think through the ideas, encouraging them to experiment with multiple technologies and instructional strategies as they taught the mathematics they had previously taught in different ways – thus examining their TPACK-of-practice.

The cross case analysis for all of the teachers exposed three themes from the blended coursework process.

1. *Throughout the practical classroom activities, the teachers were engaged in action research as they taught with technologies.* They examined and discussed various instructional strategies with their online colleagues while they considered how those instructional strategies added to their teaching, supporting student learning. They identified more student-centered discourse and grouping strategies as keys to teaching with technologies, where they guided or facilitated students in higher order thinking with the technologies.
2. *The teachers were engaged in reflective thinking about their teaching with the technologies.* These reflective actions helped them “think about how to apply the knowledge they received in their experiences for making changes in their instruction” (Dieker and Monda-Amaya 1995, p. 241). Throughout the blended course, the teachers’ reflections consistently provided opportunities to review, rethink, and rephrase their conceptions, connecting their instructional actions with students’ successful learning experiences. In essence, these experiences reconstructed their knowledge for teaching mathematics with technologies.
3. *The teachers used multiple artifacts as objects to think with while developing knowledge for teaching mathematics with technologies* (Papert 2005) *as they engaged in the reflective processes about their own teaching.* They gathered these multiple artifacts in their electronic portfolios and used the artifacts as a primary support system for their thinking and online discussions.

Conclusion

The learning trajectory for the design of the courses in the online Master's degree program provided an innovative pathway for an online progression towards restructuring teachers' knowledge with respect to a variety of teaching concerns. The results highlighted the importance of a selection of instructional tasks interwoven with specific pedagogical strategies holistically in guiding the teachers' interactions with new and emerging technologies. The trajectory framed the teachers' thinking about the role of technology in learning along with thinking directed toward students' thinking and understanding of the content with the technologies. The online instructional learning trajectory infused social metacognitive constructivist pedagogical practices that engaged the teachers in ongoing collaborations, interactions, and reflections as they examined teaching with technology.

The practical course provided opportunities for authentic inquiries into their practice in ways that challenged their knowledge-of-teaching with respect to specific teaching concerns. The online learning trajectory (Niess and Gillow-Wiles 2013) provided a social metacognitive constructivist framework for the online courses as well as the blended online practical course. The development of the electronic portfolios provided a valid and reliable process for observing the teachers' actions and thinking (Borko et al. 1997) and, thus, resulted in a rigorous examination of their teaching. The community of learners supported and challenged the teachers' thinking and reflection enhancing both shared and individual knowledge of teaching. The dynamic between building individual knowledge and shared knowledge in the instructional progression (Hodes et al. 2011; Yukawa 2006) was an important platform for building and restructuring the teachers' knowledge. This knowledge reconstruction, when integrated with the social metacognitive engagement, was where, as a group, they shared their understandings and thinking (shared metacognitive knowledge) and, based on these understandings, renegotiated their understanding (shared

regulation) (Hacker 1998). The key result was that this comprehensive instructional progression proposed an innovative pathway for incorporating online avenues for deep, meaningful reflection about their thinking and learning while supporting the reconstruction of the teachers' knowledge-of-practice for teaching with technologies – their TPACK-of-practice.

As programs expand to incorporate and take advantage of online learning contexts, teacher educators need to understand how teachers incorporate their thinking about teaching with technologies into their classroom practice – their TPACK-of-practice. The online learning trajectory used in all four of the courses in the Masters program engaged in-service teachers in knowledge-building communities, guiding them in reframing their knowledge for designing student-centered, problem-based learning with the integration of technologies. The culminating course, the blended course, revealed specific benefits of such a blending for a teacher education course. Blending the electronic portfolio tasks (where teachers individually examined their teaching with technologies) with an online community's collaboration and inquiry about instructional strategies resulted in teachers' enhanced thinking about teaching with technologies. Through this experience, the teachers engaged in (1) action research as they taught with technologies, (2) reflective thinking about their teaching with the technologies, and (3) the concurrently used multiple artifacts as objects to think with while reconstructing their knowledge for teaching mathematics with technologies. While this study identified one method for incorporating online learning to guide teachers' reconstruction of their TPACK-of-practice, teacher educators must continue to search for additional ways to guide and support teachers as they are integrating technologies in their instruction, as new and more robust technologies become available for learning tools. The challenge is to incorporate more social metacognitive constructivist features along with online environments to better reflect a more collaborative experience for today's teachers as they continue to build and reconstruct their knowledge for teaching with technologies.

Cross-References

- [Implementation of ICT in Secondary Schools](#)
- [Mathematics Education and Technology](#)
- [Modeling the Process of Information Technology Innovation in Education](#)
- [Science Education and Technology](#)
- [Teacher Education, Thinking About ICT](#)

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Robotics in Education

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Synonyms

[Machine learning](#); [Thinking computer systems](#)

Background

When Seymour Papert first introduced turtle geometry through the programming language Logo in 1967, it was intended to assist children ranging in age from 5 to 17 to learn mathematical concepts through programming and the use of words. Rather than programming using codes that were specific to a particular programming language, Papert simplified this by using common instructions to a turtle – which was first a physical robot (Fig. 1) and then later a virtual one that became an icon on a screen. Commands such as “Right 90” to turn 90° to the right or “FORWARD 20” to advance a specific distance in a straight line were used to make the turtle move. As computers were gradually introduced into schools in the 1980s, students were able to experience using a virtual turtle designed for use with Logo systems through a series of commands.

Papert’s research was rather influential particularly with the use of robots in schools. His constructionist theory emphasized that children learn most



Robotics in Education, Fig. 1 A physical robot – the (Tasmanian) Turtle

effectively when they are playfully engaged in constructing meaningful projects in the world. In 1985 he started collaborating with LEGO to create LEGO bricks that could be programmed to move. Papert’s ideas served as an inspiration for the LEGO Mindstorms kit which was introduced in 1998 and named after his book *Mindstorms: Children, Computers, and Powerful Ideas* (Papert 1980).

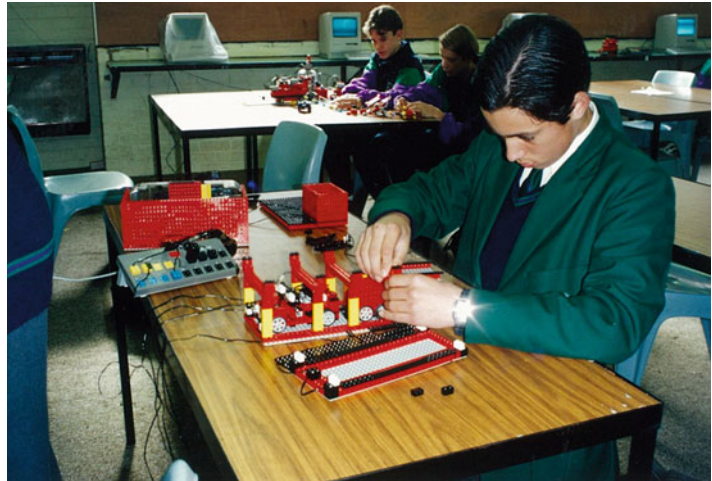
LEGO Robotics

In 1995, LEGO DACTA released the Control Lab (Fig. 2) which was designed for educational use and connected bricks to a computer via an interface box that used cables connected to the serial port of a Macintosh or MS-DOS computer. The control box provided a series of input and output ports, allowing it to control motors, lamps, and sound elements, and provided functionality of the temperature, light, touch, and angle sensors.

In 1998, LEGO Education (formerly LEGO DACTA) released Mindstorms, which was the precursor to LEGO Mindstorms NXT in 2006. The kit consisted of a variety of bricks and motors, sensors (ultrasonic, sound, touch, and light), and the NXT Intelligent Brick. The Intelligent Brick is the “brain” and allows the robot to autonomously perform a variety of operations through a programming environment. In 2013, LEGO released

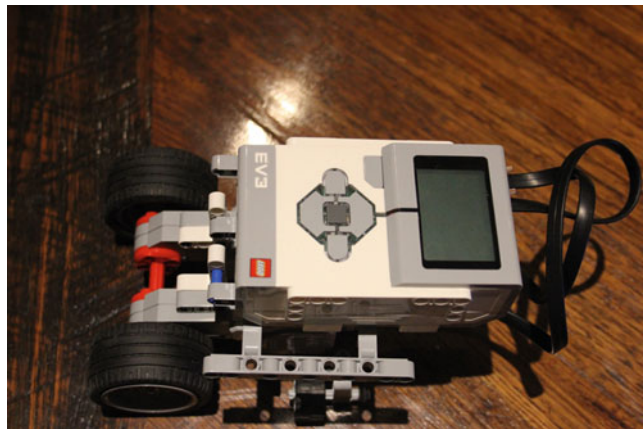
Robotics in Education,

Fig. 2 Picture taken of a student using LEGO Control Lab. (Picture taken 2/5/96)



Robotics in Education,

Fig. 3 The Intelligent Brick – Mindstorms EV3



the third generation of Mindstorms – Mindstorms EV3 allowing the Intelligent Brick (Fig. 3) to upload programs using Bluetooth or Wi-Fi as well as cables.

Mindstorms have been embraced by students globally for its ability to engage across many curriculum learning areas such as Technology, Mathematics, Science, and Digital Technologies (LEGO Education, *FIRST* Australia and QUT 2017). Students are able to work collaboratively and learn through self-directed and hands-on activities.

Robotic Competitions

There are two established organizations that run large international robotics competition: *FIRST* – For

Inspiration and Recognition of Science and Technology – and VEX. *FIRST* has four programs aimed at students in primary and secondary school:

- *FIRST* LEGO League Jr
- *FIRST* LEGO League
- *FIRST* Tech Challenge
- *FIRST* Robotics Competition

VEX has two programs aimed at school-aged children:

- VEX IQ
- VEX EDR

The mission of *FIRST* is to “inspire young people to be science and technology leaders, by

engaging them in exciting mentor-based programs that build science, engineering and technology skills, that inspire innovation, and that foster well-rounded life capabilities including self-confidence, communication, and leadership” (*FIRST* 2018b). Dean Kamen, the founder of *FIRST*, stated that his vision was “To transform our culture by creating a world where science and technology are celebrated and where young people dream of becoming science and technology leaders”(F*IRST* 2018b).

FIRST has a program aimed at younger children (aged 6–9) called the *FIRST* LEGO League Jr. Using a WeDo LEGO kit, children are given a real-world challenge, and they need to use their creativity and programming skills to design a model that moves and responds to the challenge. Students are encouraged to work in teams of up to six students and showcase their work. Unlike the LEGO League, this is more of a celebratory showcase or exposition of the work the students have done.

The *FIRST* LEGO League (*FIRST* 2018a) is an international global challenge aimed at students between the ages of 9–16 using LEGO Mindstorms. The challenge started in 1999, and the inaugural challenge focused around a group of astronauts stranded in a space station. The challenge is changed annually and is a scientific-based real-world problem that teams of students (4–10) need to solve using their design and programming skills using LEGO Mindstorms (Fig. 4). As part of the challenge, there are a number of conditions imposed

such as an 8-week time limit to analyze problem, design, and build the robot to perform autonomously using only four motors.

The *FIRST* Technology Challenge is aimed at students aged 12–17 years to encourage them in using metal and aluminum as base materials to build a robot. Teams design, build, and program their robots. This competition began in 2005 and was originally known as the *FIRST* VEX Challenge.

The *FIRST* Robotics Competition (FRC) is aimed at students aged between 15 and 18 years. A new challenge is issued each year, and students are expected to solve the challenge by building a robot that will assist to solve it. The FRC robots are designed and built in 6 weeks (from a common set of parts) by a team of senior secondary school students and a small group of dedicated industry-based engineers, computer programmers, and university undergraduates, who become the team’s mentors (Fig. 5). There are a limited number of resources that the students can use when they build their industrial robot that weighs approximately 50–60 kg. There are no limits to how big teams can be, and students build, program, and remotely control a robot of their own design. They learn to use software and hardware by working alongside professional experts.

VEX Robotics Competition is formerly associated with *FIRST*. There are two divisions of this robotics competition aimed at different age groups. VEX IQ is aimed at primary and early secondary students, and VEX EDR is for

Robotics in Education,
Fig. 4 *FIRST* LEGO
League held in Melbourne
2015



Robotics in Education,

Fig. 5 Melbourne RoboCats #5648 picture with the robot they built for the FRC



secondary school students. A yearly challenge is issued, and students design, build, program, and drive a robot to complete the challenge. In the VEX IQ Challenge, students are expected to construct a robot using the VEX IQ Robotics set by putting together plastic pieces. The sizes of the robots are similar to the *FIRST* Technology Challenge, and they use similar types of metal. The students then use software to program the robot.

Robots in the Classroom

Robots have been used in education for over 20 years; however, their inclusion into the curriculum has only normalized over recent years. Robotics are increasingly being used by younger children through technology friendly tools that encourage students to engage with them. Bee-bots (Fig. 6), for example, are a small yellow and black robot that is encased in a friendly bee design. This design is used to entice students to interact with the robot by allowing students to sequentially program the directional buttons back, forward, left, and right. Students can place up to 40 commands that allow the Bee-bot to move.

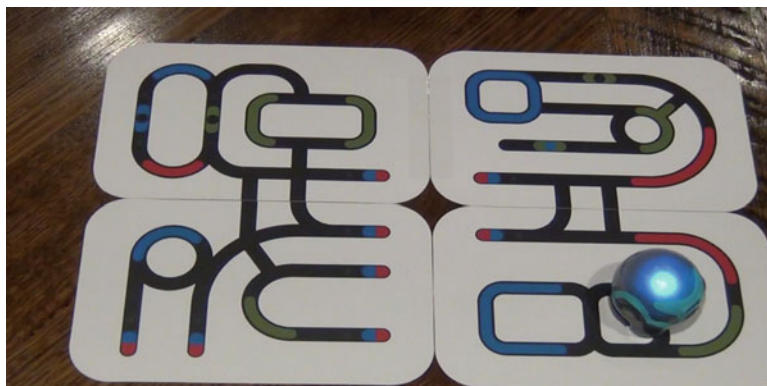
As younger children do not have adequate reading abilities, programming through color coding is another method to engage students with programming and robotics. Ozobots (Fig. 7) are



Robotics in Education, Fig. 6 Bee-Bot moving along a mat

a small robot that detects sequences of colors and performs different actions when it reads the colors. The robots can interpret approximately 25 code commands which control the speed, direction, and timers of the robots. Young students only require four markers (black, red, green, and blue) to draw the sequence that they want the Ozobot to follow along a maze. Students are

Robotics in Education,
Fig. 7 Ozobot following a
 color-coded maze



Robotics in Education,
Fig. 8 A Pro-Bot moving
 autonomously on a mat



able to control the robot by using a sequence of steps or commands through color coding.

Pro-Bots use the LOGO programming language. Pro-Bot commands are entered via a set of arrow and number keys affixed on the back of the car. The Pro-Bot will follow the sequence of commands that were entered step by step autonomously. The Pro-Bot (Fig. 8) is similar to the interpretation of the turtle; however, in this case it is shaped as a yellow car. Pro-Bots are suitable for children between 9 and 12 years of age.

Other robots that are also being used in the classroom include Sphero (Fig. 9), which is round, clear, or opaque, with a multitude of lights that change colors. The Sphero is approximately the size of a tennis ball. The robot's ability is to roll around and move in different directions

controlled by a smartphone or a tablet via Bluetooth. Although, they have been used in education with students, these devices are also seen by some to be a toy.

Other robots that are considered to be a cross between a toy and an educational robot are PLEOs (Fig. 10) which is an animatronic pet dinosaur with several body parts that move such as eyelids, legs, and its long neck. The robot uses a variety of sensors to recognize colors and patterns, listen to sounds, and react to temperature. When the robot is initially unboxed, it behaves like a newborn hatchling and needs to be raised to be mature to activate all its features. While this robot has the ability to be programmed, it is used more as a tool to demonstrate functionality of robotics and sensors.



Robotics in Education, Fig. 9 Sphero



Robotics in Education, Fig. 10 PLEO the dinosaur

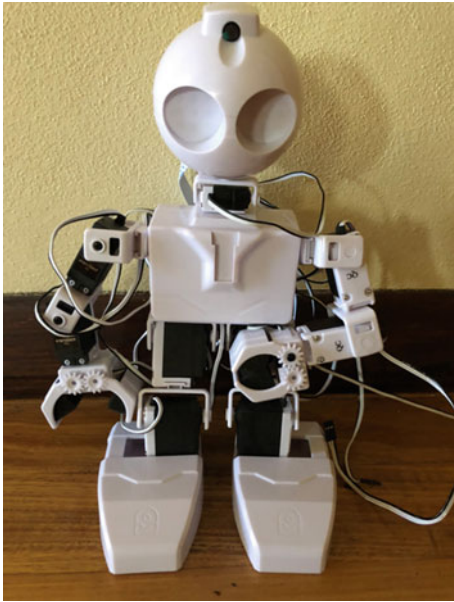
**Robotics in Education,
Fig. 11** NAO humanoid
robots developed by
SoftBank



Humanoid Robots in the Classroom

Humanoid robots such as the NAO robot have been trialed in schools in South Australia across early childhood settings and primary and secondary schools (Keane et al. 2016). These robots are preassembled and take the shape of a human form with two arms, two legs, a body, and a head. Standing at 58 cm tall, it has 25 degrees of freedom to allow movement of all of these parts. The robot senses and its moves emulate human interactions, such as sight, sound, touch, and social behaviors which can be programmed through drag and drop software or through Python code. The robots look like a child and are friendly looking, encouraging students to befriend them. While these robots show promise to be used in the educational context, the cost of each individual unit is prohibitive (Fig. 11).

From the research in South Australian schools, it was found that the technology engaged students in their learning and promoted curiosity, challenge, critical thinking, creativity, collaboration, and communication. It was found that curiosity and challenge fostered critical thinking, creativity, collaboration, and communication and that enabled the development of high-level skills in computational thinking and coding.



Robotics in Education, Fig. 12 A JD robot from EZ Robot

As robotics have moved into the mainstream, and no longer considered to be the domain of a select few, students are increasingly provided with opportunities to program and work with these tools. There are many educational robots that are being developed and used in schools each with a slightly different variant. For example, the LEGO robots require students to not only use their creativity skills to design and build their robot but to also program them. A Bee-Bot requires some programming to do a limited number of movements. A NAO humanoid robot requires programming to engage the motors, sensors, and outputs. Other variants of robots include the JD robot (Fig. 12), where the students build the robot so that it looks like the packaging. The JD robot is a Wi-Fi-enabled humanoid robot that has 16 degrees of freedom powered by gears and motors that are supplied. In addition to the ability to build and program this robot, the JD robot allows for parts to be 3D printed.

In Summary

When Papert was first advocating the benefits of robotics and programming through the constructionism theory, robotics in education was not very popular among students and schools. In recent times, robotics has become prevalent in schools and classrooms in conjunction with the elevated recognition of STEM (Science, Technology, Engineering, and Maths) subjects. Robotics has become accepted in the classroom as teachers and their students engage with this technology and the programming element of it. With already established international competitions, schools are looking into innovative methods to engage their students with technology. There is a consensus that robotics in education is valuable (Bredenfeld et al. 2010); however, the lack of empirical evidence to prove whether there is an impact in early childhood settings and primary and secondary school education still remains (Williams et al. 2007).

Cross-References

- [Programming and Coding in Secondary Schools](#)
- [Robotics in Education](#)

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Robots

- [Control Technology and School Curricula in the Late 1980s in Australia](#)

Roll Book

- [Attendance Records, Educational Management](#)

Safe Frames, Essential Determinant for Educational Technology Implementation in an Indigenous Context

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Synonyms

Aboriginal; Ethnographic Researchers; First Nation; Indigenous; Postsecondary Learners

Introduction

This paper describes the requirements for a safe frame in teaching with and researching on educational technologies among an Indigenous community in Northern Manitoba, Canada. Following abuse and misuse of access privileges by researchers, policies were created for conducting research in Indigenous communities that are protective of Indigenous research communities and their members. As a result, all researchers including outsider researchers who intend to conduct research in these contexts must comply with these established policies and

protocols. Despite these frameworks, the success of a research is not guaranteed.

The concern for entry into an Indigenous community for the purposes of conducting a research emerged during my doctoral studies which was based on a study that examined how Indigenous adult postsecondary learners in this remote Canadian Indigenous community would adapt and orient themselves between Eurocentric and Indigenous cultural ways of learning. The study utilized digital technology such as mobile phones in producing documentation for adaptive and orienting between these ways of learning.

The study was conducted in a rural Indigenous community that was situated over 940 kms north of the closest large urban city. With a population of about 2000 inhabitants, one elementary school, a high school, and a distance education learning center, this community is geographically far removed from the reach of urban education. Educators who facilitate learning have to periodically travel by air to do so or go via ice roads during the winter seasons.

Thus, digital technologies, such as video- and conferencing, present an interesting alternative to accessing learning materials for learners in this community. With the recent implementation of a third-generation mobile network, learners were presented with another interesting opportunity to leverage mobile devices to either access content, engage in collaborative learning, or even participate in further research.

Despite these alternatives, the larger question concerned the state of pedagogical preparedness of instructors, the level of administrative readiness of educational institutions, and the positionality of learners to utilize these technological advancements as tools that could enhance student learning in the research community.

Much of these concerns were examined in the thesis (Akoh 2016a), in which a framework was produced to (a) guide policy makers, government agencies, school administrators, educators, and students to better collaborate for negotiated learning and adaptations, (b) trigger recognition of the importance of these movements as an essential learning element in indigenous communities, and (c) cause an exploration of the more intrinsic functions of Internet technologies, specifically mobile technology, to facilitate learning negotiations.

This paper however addresses an aspect of the larger study related to the need for constructing a safe frame for research participants who were also students in the distance education learning center. Parallels could be drawn between the research and teaching as the study activities were learning based.

As a non-Indigenous Canadian researcher, conducting a technology-based research in an Indigenous context, there were strong issues of access, even more so, in a policy-protected research context. The policies required researchers to abide by protocols and ethical practices that protect the research community, the people, and Indigenous knowledge from exploitation and “predators and biopiracy” (Battiste 2005). Exploitative research practices had left a bad taste in the mouths of Indigenous communities. This paper is based on a conceptual safe frame (Miller 2001) that was used during the study. It is presented here to elaborate on the need for a safe frame as an essential requirement for conducting research and for teaching in contexts where access may be limited, where differences of cultural backgrounds exists, and where technology is used as a tool for learning. The paper has six sections.

In section “[Contextual Background](#),” the contextual background of the study is described to

present the reader with the physical challenges involved in conducting a technology-based research in a rural community where Internet and mobile access is minimal. This section also describes the policy framework required for researchers to conduct studies in these communities. In section “[Insider/Outsider Research Dilemma](#),” the dilemma of conducting a research as an outsider is presented. This complexity requires the researcher to provide higher levels of assurances, beyond adherence to the policy frameworks such as the need to construct a safe frame. This is discussed in section “[Safe Frames](#)”. Section “[Safe Frames as an Essential Determinant](#)” describes the constituents of a safe frame in research community.

Contextual Background

Canadian Indigenous population is known as Aboriginal. Aboriginal population consists of First Nations, Inuit, and Metis peoples who represent about 4% of the Canadian population as at the 2011 census. First Nations people represent 2.6% of the Aboriginal population, Metis represent 1.4%, and Inuit represent 0.2%. Together, they consist of 1.4 million people identified with an Aboriginal identity (StatisticsCanada 2011). Fourteen percent of this population resides in Manitoba where this research was conducted.

Although the numbers are improving, Aboriginal people aged from 25 to 64 with a postsecondary qualification are at 48.4% compared to 64.7% of non-Aboriginal students with a postsecondary credential in 2011, up by nearly 6% in 5 years. About 14.4% have a trades certificate (cf. 12% of non-Aboriginal), 20.6% with a college diploma (cf. 21.3% of non-Aboriginal), 3.5% with a university certificate below a bachelor level (cf. 4.9% of non-Aboriginal), and 9.8% with a university degree (cf. 26.5% of non-Aboriginal) (STATSCAN 2016). Aboriginal students represent about 3 to 4% of the undergraduate student population in Canadian universities and colleges (TRC 2015; AUCC 2011). Only “8.7% of First Nations people, 5.1% of Inuit and

11.7% of Metis have a university degree, according to the 2011 census” (TRC 2015).

Younger Aboriginal people in the 35–44 age bracket have proportionally higher levels of education at 68% than their counterparts in the 55–64 age bracket at 58.7% with a high school diploma. Younger Aboriginal women have 13.6% compared with 10.2% of their older counterparts with a university degree.

Despite these improving numbers, attrition rates are high and continue to plague Indigenous education (Demmert 2001; Raham 2009; Kirkness 1999; Akoh 2016b). Improving education numbers is one of the many areas of research involving Indigenous peoples. Health, social structures, economic development, and learning technologies (Mignone et al. 2011) are some of the other areas of research. Researchers in these areas perceptively intend to contribute research that benefits Indigenous communities and their people, even though Indigenous people feel they “have been researched to death” (Schnarch 2004).

Private, public, academic, and individual research have been conducted in Indigenous communities, with researchers treating community people as “merely a source of data,” implementing research programs without community knowledge or even consulting with them to determine “what kinds of projects might serve their needs” or to treat Indigenous peoples as partners in the research (Schnarch 2004). In some cases, researchers have used collected information against them.

Consequently, ethical protocols and principles have been developed to protect research integrity in Indigenous communities. One of such protocols and principles is the *Ownership, Control, Access and Possession* (OCAP) (OCAP/FNIGC 2013) protocol which guides research “monitoring and surveillance, surveys, statistics, cultural knowledge, and so on” (Schnarch 2004). The protocol essentially grants ownership of all information collected during the research to the community involved; the community can control how the information is used, can manage the information and make decisions about its use, and can assert ownership on the information collected during the research. Although OCAP was

meant for the health sector, its reach spread broadly to all forms of research.

In addition to OCAP, the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* and the *Integrated Knowledge Translation* framework ensure that researchers leave research knowledge behind for the benefit of the research community (GC 2014; CIHR 2011). These frameworks are among the many other ethical guidelines researchers are required to meet. In addition to these frameworks, universities set up ethics committees who prescribe institutional guidelines and grant ethics approval for research on human participants. For instance, the study from which this paper emerged was granted ethics approval by two universities, the University of Manitoba, Education Nursing Research Ethics Board (ENREB), and the University College of the North research Ethics Board (UCN-REB). Both universities had to grant research ethics because the former is the degree-granting institution and the latter is the host institution responsible for delivering learning to the research community.

These formal structures were necessary for access to the research community, and they provided the ethical core necessary for conducting research that involved Indigenous participants and their communities. Similarly, additional community-based protocols that involve acquiring the permissions and consent of the Chief and Council, a local governing board involving elders of the community, have to grant access to the researcher prior to the commencement of research.

But compliance to these formal structures alone is insufficient for successful research, and does not guarantee research participation by participants. For instance, the overarching study from which this paper is based utilizes purposeful sampling as a recruitment approach for research participants (Suri 2011; Patton 1990; Coyne 1997). Purposeful sampling allows the researcher to sample and select “information rich cases for in depth” study. Other important elements that guarantee the safety of, and instill confidence in, the research participants are required in order to secure active participation. Collectively, these

formal structures such as the policy frameworks, community-based protocols, and the confidence of research participants are required to create a safe frame that is essential for successful research and, by extension, teaching, in Indigenous communities.

Another layer of complexity concerns my role as a non-Indigenous Canadian with an Indigenous African/Nigerian background, often described in ethnographic research as insider-outsider dilemma (Merriam et al. 2010; Dwyer 2009; Kersen 2016). This role is significant to the construct of a safe frame.

Insider/Outsider Research Dilemma

Researchers who share the same identity, language, and experiential base with their study participants are called insider researchers (Dwyer 2009). Their position improves legitimacy, increases acceptance, enhances open communications between participants, and engenders trusts between researcher and participants. A significant benefit for insider over outsider researchers is access, preexistent entry, and common ground to the research community. The insider researcher has a “starting point (the commonality) that affords access into groups that might otherwise be closed to outsiders” (Dwyer 2009).

Most ethnographic researchers experience insider-outsider dilemma during research (Merriam et al. 2010; Thomas et al. 2000). Even studies that are systematically designed using an insider-outsider approach are confronted with challenges including the potential fragility of the research team, the need to constantly maintain relationship with the research participants, and the need to completely adhere to ethics, confidentiality, and privacy of the research participants (Thomas et al. 2000).

I approached this study as a Canadian of African descent disadvantaged as a non-Indigenous researcher and who was an outsider to the research context. The definition of indigenous people remains variable because “only indigenous peoples could define indigenous peoples” (Cornthassel 2003). For context, however, it

is used here to represent persons and communities situated on a land and within a local context such as the Aboriginal people of Canada or a Canadian of Indigenous origins from the Idoma people of Nigeria from where I originate and with which I self-identify. Yet, as an indigenous African/Nigerian in Canada, I do not qualify as an Indigenous Canadian of Aboriginal descent.

Nonetheless, my research interests concern Indigenous people broadly and Aboriginal people specifically. Thus, the struggle for ownership, identity, and relevance of my research becomes important, as well as the ownership, control, access, and possession of the research data. One important struggle relates to whether my identity as a non-Indigenous Canadian can conduct or situate self within the peripheries of Indigenous research. Although I self-identified as Indigenous based on my African/Nigerian origins, there remained a fundamental difference between my Indigenous African roots and that of my Canadian research community. Further, the aforementioned perceptions of researchers by Indigenous communities were never in my favor, to begin with.

Despite the differences, there are commonalities I shared with my research context that benefited the research outcome. While I understood the insider’s direct relationship with the research context, outsiders seemed to provide useful and corroborative experiences and perceptions that benefited the research context and participants (Dwyer 2009; Thomas et al. 2000; Damianakis and Woodford 2012). The boundary between the insider and the outsider, though large, directly or indirectly seemed to affect them both, as outsiders provided perceptions from the outside that benefited insiders. For the outsider, it is a conflict of positions that mostly questions the authority he/she has to conduct the research, to whom the intellectual property of the research belongs, or the ethical grounds by which the outsider must stand on to express an insider phenomenon (Damianakis and Woodford 2012).

The insider-outsider context provided further complexity to the study and, even more so, necessitated the need for constructing a safe frame.

Safe Frames

The concept of safe frames emerges from social and health work (Miller 2001; Campling 2001). They have their histories in “therapeutic communities” described as “small cohesive communities where patients have a significant involvement in decision-making and the practicalities of running the unit” related to their wellbeing (Campling 2001). It is the responsibility of the staff in these units to provide a safe frame for patients’ involvement in the treatment process. Safe frames engender a culture of enquiry and shared ownership of understanding, and not perceived to be the sole prerogative of the social worker.

Constructed safe frames allow patients to increase confidence in the health worker such that they are willing to “express distress or ask for help in a constructive manner” (Campling 2001). Within the context of a therapeutic community, Campling describes the need for a safe frame, especially for patients that could potentially act in a destructive manner, as follows:

The task is to provide a safe frame within which they can explore intrapsychic and interpersonal problems and find more constructive ways of dealing with distress...The structure of a therapeutic community, with its community meetings, diverse network of relationships, supportive peer group, strong sense of belonging, 24-hour support, structured day and clear rules and boundaries owned by the residents, means that a strong therapeutic attachment can be forged – an attachment that can withstand high levels of aggression and risk. (Campling 2001)

This concept of safe frames is not too distant from Miller’s, who draws similarities to health practices and teaching by advocating for a safe frame for learners involved in trauma studies (Miller 2001). Miller warns that instructors who teach students who are learning about trauma should be aware that exposure to content, literature, and trauma cases could have far-reaching consequences on students’ inner experiences. Some students may have been “exposed to traumas or losses in their adult lives, including domestic violence sudden death within one’s family, serious illness, or other workplace trauma, further compounding the impact of studying

about trauma and treatment (Miller 2001). Miller suggests that teachers should become more attuned to their own, and consequently, their students’ reaction to learning materials. Further, teachers should “differentiate the classroom experience from the therapeutic personal experience” (Miller 2001) and introduce journal writing to allow students express their responses to trauma exposure. Miller describes a learning safe frame as a safe environment that is available:

both for the individual student, and for the collective classroom experience...It is the instructor’s presentation of educational focus, tone, boundaries, and frame for the class that can define the parameters of the class discussion and shared expression...Learning in the context of trauma also is deepened when a climate of safety is provided. Because the intensity of this learning and experiencing environment affords deep awareness, and also replicates the original fields of interaction, attention to safety is further required. (Miller 2001)

Participants in the study captured in this paper have historically been known to experience trauma and have engaged in self-harm practices. For instance, suicide rates among Canadian Indigenous learners continue to increase, requiring that the government engage more actively to mitigate its impact on the future of young Indigenous peoples (TRC 2015; Toulouse 2013; Dunlop 2016; Eggertson 2015; The Government of Canada 2016). Further research may be required to draw correlation between the increasing use of digital technology and the growth in suicide and self-inflicted injury numbers among members of this community. However, there was evidence of cyberbullying in the research community as community members became more conversant with the use of digital technologies. The impact of this on learning and research is discussed further below.

Safe Frames as an Essential Determinant

The study examined how Indigenous adult post-secondary learners who are located in a remote community in Northern Manitoba, far from the reach of urban education, were able to negotiate their learning by adapting and orienting

themselves between Eurocentric and Indigenous learning methods. Using digital technology such as mobile phones, participants produced documentation about these adaptations and orienteering. The aim of the study was to identify the determinants of these negotiated learning and adaptation. A useful application of the outcomes of the research is its contribution to knowledge and its potential for addressing Indigenous education challenges such as high attrition and low participation rates among Indigenous learners.

The research methodology was phenomenology, allowing participants to provide more in-depth and contextual data about their negotiated learning and adaptation (Creswell 2006). Through narrative inquiry, participants responded to questions about their lived experiences (Clandinin and Connelly 2000).

A total of 14 participants were recruited into two participant groups: eight (8) primary research participants were directly involved in research activities, and six (6) secondary participants were interviewed only to provide contextual information to the study. Participants were identified using purposeful sampling (Suri 2011; Coyne 1997), which allowed for sampling and selection of “information-rich purposeful cases for study in depth” (Patton 1990).

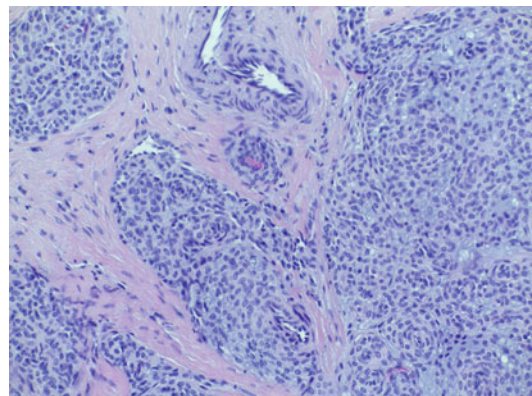
Participants utilized their personal mobile devices including iPhone, iPods, smartphones, iPads, etc. and the apps on them such as camera, voice recorder, and video recorder to capture video, voice, and data of the interviews they conducted of their family, community, community members, and themselves. Participants interviewed family members on culture-centric questions related to their cultural histories and traditions, such as original birthplace, family history, level and type of Indigenous education received, housing structures, transportation, parenting styles, traditional medicines and ceremonies, and strategies for survival.

Upon gathering this information, participants analyzed the responses and then produced individual reflections of their own learning practices, which they recorded as video and voice and on blog posts or notebooks. They were consequently interviewed, using the overarching research

question, “what are the determinants of technological adaptive orienteering among adult learners in your community?” Their responses provided the primary data for the research.

Upon analyzing the data, various themes and sub-themes emerged and were categorized. One emergent thematic area concerned the impact of digital technology on the local culture such as its role in enhancing existing traditional practices and in erasing, preserving, or making it obsolete (McLuhan and McLuhan 1988). Some participants felt that digital technology had increased vulnerability and created exposure to cyberbullying. This outcome highlighted the need for the construction of a safe frame during classroom learning. The constructed frame had four levels (see Fig. 1).

In describing the contextual background of this paper, I described the research policies that had been put in place to guide research in Indigenous communities. These policies such as the *Ownership, Control, Access and Possession* (OCAP) (OCAP/FNIGC 2013), the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans*, and the *Integrated Knowledge Translation* framework (GC 2014; CIHR 2011) are frameworks defined by government departments to protect Indigenous communities from unscrupulous researchers. These policies are also applicable for teaching. They are the first-level components of the safe frame.



Safe Frames, Essential Determinant for Educational Technology Implementation in an Indigenous Context, Fig. 1 Safe frame

The second-level components are the institutional ethical frameworks, which provided students, researchers, and educators with the boundaries for their work and prevented them from undertaking activities that could negatively impact human participants. It also allowed participants to become familiar with the extent of their involvement in the process. Participants have the option to opt out and can withdraw their complete participation in the process.

The third level of this safe frame concerned the culture-centric responsibilities of the researcher to the research community. This level required the “blessing” of the elders in the community. The research design was presented to the Council of Elders, to offer suggestions and to grant permission prior to conducting research activities.

Even with the blessing of the Council of Elders, participation in the study is not guaranteed, resulting in the construction of a fourth level of this safe frame. Participants may be present but may not affectively engage in the research. This form of participation will not produce the level of depth nor generate the quality of data required. Because cultural practices were nuanced to the research community, they cannot be generalized. Relationships were established directly with the community members to construct this level of the frame. This involved constant visit to the research community, building relationships with research participants, engaging with the local Elders and Council of the community, and presenting the research in a transparent manner to them. Parts of this frame involve making full disclosure about the research, proceeding cautiously by ensuring that the availability of researchers are respected, respecting the time constraints of the participants while adjusting activities to fit their schedule, and ensuring that the research outcome involved “giving back” by adhering to the promise to leave research knowledge with the community upon completion (Akoh 2016b).

Discussion

The components of the frame described earlier had to be developed by and for the research

community. Successful research could not be conducted solely upon promises to abide by ethical principles. Carefully constructed respectful relationships with the research community and potential research participants were essential. The notion of developing relationships with the research community prior to commencement of the research would have been in direct conflict with the requirements of existing ethical frameworks, which prevented researchers from making contact with the research community prior to the commencement of research activities. A safe frame will not contain this component, and could be even more stringent for outsider researchers seeking to conduct a study in an indigenous context, thus making the frame fragile.

It was necessary to develop confidence in the research participants. To do so, engagement with the research community took over 2 years to develop, involving regular travels to community, presenting papers and research ideas with the Elders and Council, and at conferences hosted in the community, and even living in the community while conducting the research.

Participants had to feel safe by constructing a requirement for confidence in the safe frame. This level of confidence was tested when participants’ personal traumatic experiences surfaced resulting in their unavailability to participate and unwillingness to communicate about their traumatic experience. The constructed safe frame was fragile requiring a more affective and self-conscious approach to the research activities, described as a personal code of ethics and captured in this self-reflection:

A personal sense of ethics derived from a feeling of having experienced trauma of the other. We cannot be empathetic towards another if we ourselves are not in the position of the other. . . we have a personal sense of ethics towards the other; we would not impose our ways and times of doing things on them. Rather, we will concede that they have their challenges and from this, we find ways of adapting to their learning using their time. We cannot impose our time on them (personal reflection).

The self-consciousness, to be cognizant of this safe frame, may be unrequired for an insider researcher, but it is of prime importance to an outsider researcher, more so in the context of

technology use. Outcomes from the research indicated that the use of social media on mobile devices resulted in creation and transmission of inciting messages that heightened the trauma of community members. Cases of cyberbullying increased as community members made social media posts with little consideration to the feelings and emotions of their target recipient.

Arguably, the boundaries of the safe frame dissolved when community members used digital technologies and social media for interaction between themselves but erected them when outsider participants/researchers were involved. It would appear that a safe frame was not required when community members interacted with each other; the frame tended to dissolve under the illusion that the sender and receiver of messages did not need it.

Three important conditions were required in the construction of this safe frame, (a) a feeling of safety, (b) assurances of privacy, and (c) guarantees of equity.

(a) *Safety*

Participants were critical of the digital technology used in the study. They expressed wishes of safety concerning the use of digital technology, even though they had owned and used them prior to the research. One participant expressed the need for this feeling by requesting that the outcomes of the research benefit the community, that the application of digital technology in this context was done in a safe way without harm to the community members, and that community members, including elders, parents, and teachers, are constantly consulted throughout the research. Remembering the potential for cyberbullying and self-harm, participants recalled the need for much safer and happier times of the past, prior to era of digital technology when community members live in peace and there were not many incidences of traumatic experiences.

(b) *Privacy*

A second condition for this frame included assurances of privacy. Participants expressed the need for privacy by suggesting

that privacy exceeded merely keeping communications within the boundaries of the safe frame. Participants wanted to be assured that data loss would not occur and personal information would not fall in the wrong hands. Participants had to develop their own levels of confidence and assurances in the use of the digital technology as they were informed of the privacy requirements of each digital tool and the extent to which violating privacy rules could lead to loss of data or misuse.

(c) *Equity*

A third important condition is the need for equitable relationship between participants, researchers, and potentially their instructors. Even though participants were aware of the power relations present between them and outsider researchers and instructors, a safe frame would be destroyed if they felt their culture was being undermined, especially in the light of ongoing perceptions about “cultural genocide” that undermined their culture in relation to Eurocentric culture (Battiste 2004, 2005; TRC 2015).

These conditions were necessary within the safe frame. Through the construction of a safe frame that encompasses these policies, community protocols, and conditions, successful access to the research community was attained. However, it was the outcome of the research, such that it benefited the research participants and their community that was strongly highlighted.

Conclusion

The notion of safe frames is described in this text so that future researchers and teachers in Indigenous communities, who use technology, may be able to produce research and learning outcomes that seek to benefit community members and the context in which their research is performed. The objective is to address challenges with Indigenous learners where there may be a need to scaffold their learning from a cultural based with which they are more familiar

to a less familiar base such as an Eurocentric learning worldview. Digital technology, such as mobile devices, appropriated within Indigenous context and utilized in a culture-centric manner, and in compliance with a constructed safe frame, holds promise in addressing some of the challenges of adult learners in Indigenous communities.

This paper describes aspects of a larger study in which digital technology was used as a tool documentation of adaptive and orienteering movements from Indigenous ways of learning to Eurocentric ones undertaken by adult learners in a Northern Indigenous community in rural Manitoba. The research was conducted by a non-Indigenous Canadian in an Indigenous setting, which provided some levels of entry complexity to the researcher. In compliance with the various policies and protocols in place, access to conduct research in this community was not sufficient, hence the need to construct a safe frame that assured research participants of the levels of confidence they needed to actively engage in the study.

This study does not intend to generalize this aspect of its findings as a rigid structure of safe frames. In fact, safe frames are nuanced to the communities in which the research or teaching is delivered. It is the responsibility of the researcher or educator to develop the most appropriate frame consisting of the elements that could address the needs of their specific community. Thus, more nuanced research is required.

The research presented in this paper, however, highlights three important aspects: (a) that safe frames are a required construction in research context where trauma and self-inflicted harm are prevalent; (b) that digital technologies, especially mobile devices, could play a significant role in understanding the cultural nuances in the research community and are necessary for highlighting the pedagogical applications of digital technology; and, finally, (c) that constructed safe frames may be the missing piece in understanding and addressing learning problems that are evidenced by symptoms such as high attrition and low completion rates among adult learners in Indigenous learning context.

Cross-References

► Digital Technologies and Literacy Contexts for Young Indigenous Children

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SAMR Educational Model

- Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption

Samsung Galaxy Tab

- Tablet Use in Higher Education

School

- Rationales for Information Technology in Schools, Historical Perspective

School Bullying

- Ethics and Learning for Teacher Trainees, Team-Based Simulations in Cases of Bullying in School

School Culture

- Computer-Based Training and School ICT Adoption, A Sociocultural Perspective

School Improvement

- Computers and Educational Improvement
- Support for School and Institutional Improvement and Accountability

School Leadership

- [Computer-Based Training and School ICT Adoption, A Sociocultural Perspective](#)
- [Support for School and Institutional Improvement and Accountability](#)

School Management Software in a Primary School in Victoria, Use of

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Synonyms

[Applications](#); [Educational management systems](#); [Primary schools](#); [Software](#); [Victoria](#)

Introduction

Computers were being used in management applications in some Victorian schools long before the Department of Education got involved in providing administrative software for schools in the mid-1980s. Some schools, in which a particular teacher had an interest in computing, used teacher-designed BASIC programs on Apple// computers for things like scheduling and recording information about the school sports, for word processing in the school office, for assistance with timetabling, and for listings of students in each class. These were very much single school applications (Tatnall 1995).

Every school needs to store large quantities of administrative data relating to matters concerning individual students, groups of students, parents, teachers, events, and curriculum. This entry reports on how one primary school in the Australian state of Victoria makes use of its educational management systems.

Australia is a federation of six states and two territories. The Commonwealth Government is based in Canberra, but school education is the province of the state governments. Government schools in Victoria enroll only about 68% of Victorian students, the remainder being catered for by the independent and Catholic schools (Victoria State Government 2018). This entry deals only with management systems in Government schools.

Hurstbridge Primary School

Hurstbridge Primary School is situated in the semirural town of Hurstbridge 32 kms northeast of Melbourne. The picturesque setting of the school, newly constructed in 2005, is set among the gum trees along the Diamond Creek and provides a magnificent environment for members of the school's community. The school comprises two main wings, a library and computer lab, art room, music room, instrumental music rooms, aftercare room, hall, and science and Italian room (Tatnall and Tatnall 2014, 2007; Hurstbridge Primary School 2018).

In 2018 the staffing profile consists of a principal and assistant principal and ten classroom teachers and specialist teachers. Chris Tatnall is the school principal.

Administrative Systems in Victorian Schools and Their Use at Hurstbridge Primary School

There are two categories of application software used in Victorian schools: curriculum applications and administrative applications. To keep these separate, schools have two entirely separated and unconnected networks:

- A Curriculum Network that is accessible by teachers. This can be accessed throughout the school using either Ethernet or Wi-Fi connections.
- An Administration Network that is accessible only to school management and school

administrative office staff, but not to teachers. The Administrative Network is accessible only via an Ethernet connection at specific locations.

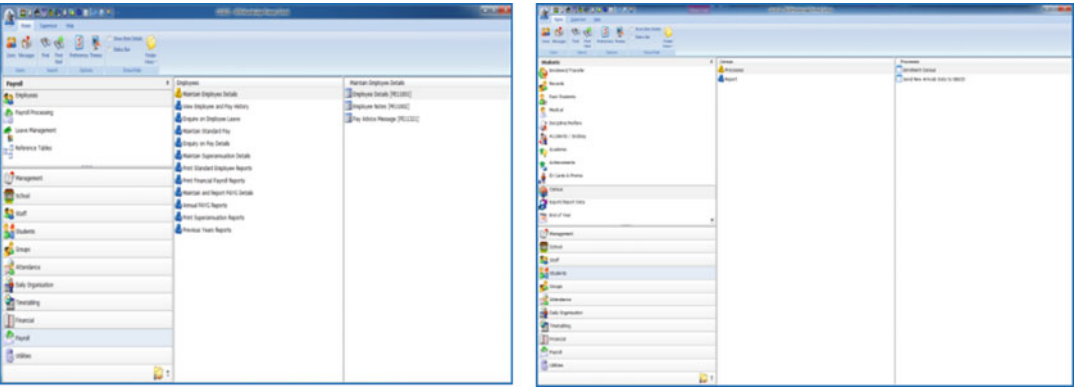
CASES21

In the early 1980s, a newly elected Victorian Government found that it was not possible for it to get consistent financial data from all its governments departments, as each had its own accounting system (Birse 1994). This meant that the government was unable to draw up a balance sheet for the State of Victoria as a whole and as a consequence it quickly decided to set up accounting standards that would be used by all government departments and to institute a centralized accounting system (Tatnall 1995). In the case of the Department of Education, with the aim of making schools more centrally accountable, this system *imposed* an unalterable chart of accounts, which for small primary schools was seen as unnecessarily complex. Birse (1994) suggests that “the system was definitely not set up to empower schools. It was fairly imposed, and from that point of view they got it wrong.” The result was CAAS (Schools’ Administrative Systems Development Unit 1987) where the development philosophy placed emphasis on an integrated database management system: “All school records should be part of an overall construct where a general information system comprising students, staff, assets, facilities and financial data is readily available to school-based personnel to assist in the

administrative process” (Directorate of School Education 1993). CAAS was designed to be used with MS-DOS and a later version became known as CASES. Since that time CASES has been through several different versions culminating in CASES21 which, in 2018, is used in all Government schools in the state (Fig. 1).

The Computerised Administrative System Environment in Schools (CASES21) (CASES21 is a customized version of the Maze school software system, marketed commercially by CIVICA.) provides support to Government schools for administration, finance, and central reporting (reporting back to the Department of Education). CASES21 runs on a Windows PC within the school and is claimed to have been designed to be easily modified to meet evolving school business needs. It currently has two main modules:

- **Administration module:** student and family records, photos, enrolments and census, student medical records, welfare, accidents and sick bay, attendance, student achievement, incidents, discipline and merit, activities, excursions, home groups and houses, staff records and photos, daily organization and calendar, timetabling, school details, management, and council and parents’ clubs.
- **Finance module:** payroll; staff records and leave for school-level employees; student, family and sundry debtors; creditors; asset



School Management Software in a Primary School in Victoria, Use of, Fig. 1 CASES21 (a customised version of the Maze school software system)

register; budgets; reporting; and end-of-year and end-of-financial year (Department of Education and Early Childhood Development 2011a).

The use of CASES21 is mandatory for all Government schools, and all school data is stored on-site but automatically backed up online remotely by the Department of Education. This means that the Department of Education can create its own reports from any of the school’s data and the school doesn’t need to send it anything. Within the school, CASES21 is used by school management and office staff with no direct teacher access. CASES21 is linked to most other management systems within the school and to the Department of Education.

Apart from assisting schools with some administrative tasks, perhaps the biggest difference made by the introduction of CASES21 was the flow of information back to “Spring Street” – the location of the Department of Education (Its location is Treasury Place, Spring Street.). It is now very easy for someone in Spring Street to obtain details of the finances, enrolments, teachers, students, and maintenance requests for any school in the state.

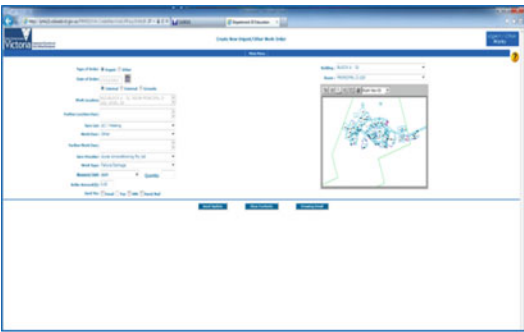
Financial matters are now handled by office staff in the school, but the Department of Education has online access to all this data at any time. Use of CASES21 makes the task of handling finance, record keeping, and enrolments by the school very much easier.

School Maintenance System (SMS)

Audits of all (Government) schools are carried out each financial year by the Department of Education to determine the maintenance needs of each of their buildings. Based on priority considerations, it then determines works to be included in its maintenance program, and the prioritized data is loaded onto the School Maintenance System (SMS) in order to assist with its statewide maintenance and infrastructure planning (Department of Education and Early Childhood Development 2013). SMS is accessed online and linked to CASES21 (Fig. 2).

At the school level, SMS is used to assist with buildings and facilities, property management, repairs, and urgent works. At Hurstbridge Primary School, it is used mainly by the assistant principal and the school office staff. As SMS works online, the Department of Education is always easily able to see the school’s spending patterns and to check to see that the cost of all maintenance, repairs, and urgent works is within the school’s global budget. An important feature of SMS is for tracking urgent works, which is done automatically.

Before introduction of this fairly new system, purchase orders to a contractor for any school maintenance tasks had to be handwritten at the school and then sent off to CASES21 for Department of Education approval. Now, after the school has set up the system with contractor names and other details, when maintenance is needed, it sends an order to the contractor and also enters



School Management Software in a Primary School in Victoria, Use of, Fig. 2 School Maintenance System (Department of Education and Early Childhood Development 2018c)

this directly into CASES21 where all the data is stored remotely. The school office staff then just pay the bills from CASES21, making it easy for the school to track spending.

This system is also used for routine inspections and occupational health and safety issues. Once set up, the system remembers dates for checking and ordering of these inspections. Use of this system has made these school administrative tasks a good deal easier.

EduPay

While selection and appointment of teaching and administrative staff is done at a school level, the Department of Education manages the payment of all salaries. The Department's HR and payroll system – EduPay – is web-based and designed to enable viewing of up-to-date leave and salary information. It also allows school teaching and administrative staff to access their payslips, to apply for leave, and to view and update their contact and banking details (Department of Education and Early Childhood Development 2018a). It also is linked to CASES21.

Recruitment and position advertisements are done via the EduPay website. Schools list their new teaching jobs and openings over the weeks on the EduPay website, and then this is transferred to the Department of Education "Recruitment online" website. Using this system is the only way in which teachers can apply for new positions. The way that this is done is that the teacher writes a job application, taking care to take note of the selection criteria, and then uploads this as a PDF onto the recruitment online website. Recruitment online then automatically sends emails to prospective applicants to tell them whether they have been shortlisted, not shortlisted, or successful. If they are successful, then EduPay sends out their employment contract.

EduPay is also used by staff in schools to track their performance. Each staff member, teaching and nonteaching, is required to enter a Performance and Development Plan (PDP) each year. This plan sets out what the staff member is hoping to achieve during a 12-month period. The principal will use EduPay to approve and sign off on each staff member's plans. The

principal also makes comments on the plans during the staff member's reviews each year. This plan is linked to the principal's PDP and also the school's strategic plan (Fig. 3).

For quite some time, teachers have been paid by direct bank transfer rather than by check. Before the EduPay system, teachers were sent payslips each fortnight with information about this pay, leave, etc. All this information is now provided online. Whether this is better is a matter of personal opinion: some teachers are happy with this, while others would prefer a printed payslip rather than having to go online to check.

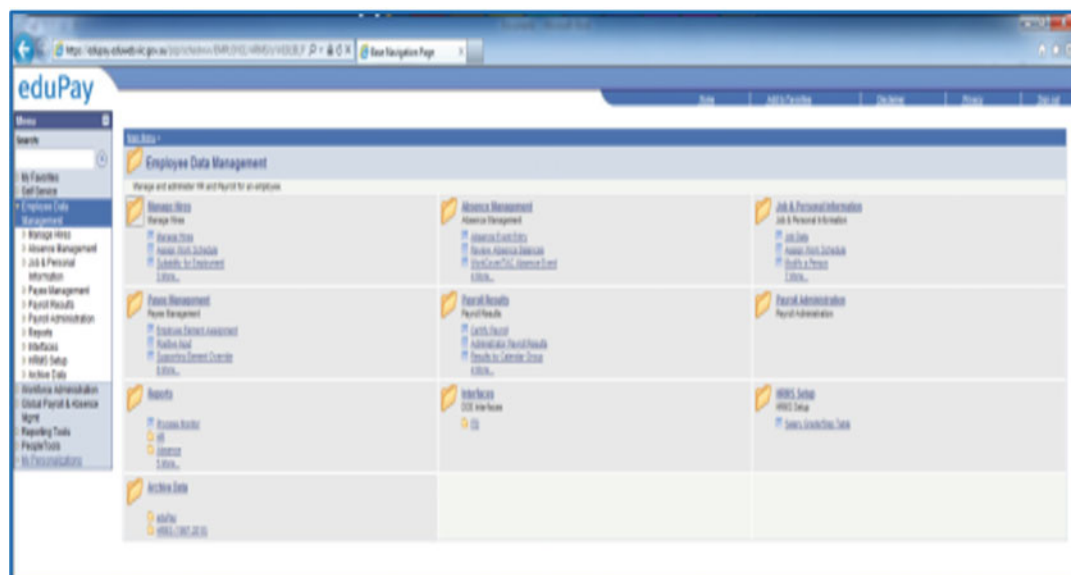
Program for Students with Disabilities (PSDMS)

PSDMS has been designed for use by schools to provide information about support processes associated with funding applications, eligibility evaluations, and budget reporting for students with physical and intellectual disabilities. This program provides funds for teacher aids to assist these students, and not for facilities or equipment. PSDMS also is linked to CASES21 (Fig. 4).

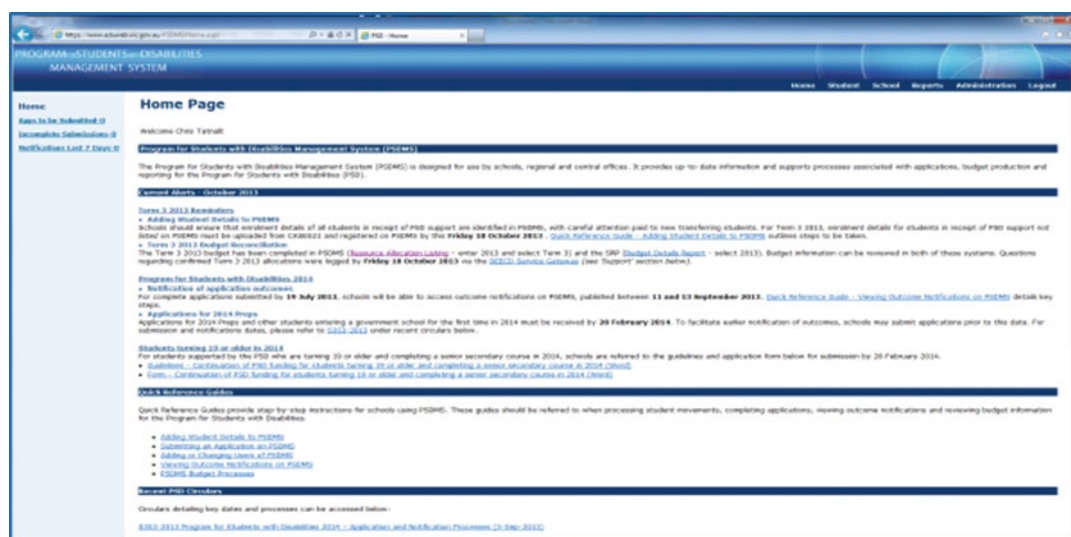
The school has found that the system's provision of information about support processes associated with funding applications, eligibility evaluations, and budget reporting for students with physical and intellectual disabilities is a big improvement on doing this by hand.

Ultraset

The Ultraset (now discontinued) was designed as a web-based system to support delivery of curriculum, online teaching and learning, and sharing of knowledge across all Victorian Government schools (Department of Education and Early Childhood Development 2011b; Tatnall et al. 2013). It began its service to all Victorian Government schools in September 2010. It had many of the features found in a business extranet in that it was closed to people outside the Victorian Government school community and required a username and password to gain access, but with over 500,000 users, it was a good deal larger than most business extranets. The Ultraset's intended users were school teachers, as well as school students and their



School Management Software in a Primary School in Victoria, Use of, Fig. 3 EduPay (Department of Education and Early Childhood Development 2018a)



School Management Software in a Primary School in Victoria, Use of, Fig. 4 Program for Students with Disabilities (Department of Education and Early Childhood Development 2018b)

parents, all of whom would be issued with usernames and passwords.

The Ultranet was potentially an innovative technology that could have provided value to

the Victorian education system, but for a variety of reasons (Tatnall et al. 2013; Davey and Tatnall 2014), it was not successful and was discontinued at the end of 2013.

Compass

Many schools have taken on new student management systems to link in with other systems provided by the Department of Education. There are many companies providing these systems, under private arrangements with schools, but the Department of Education does not cover the costs of these systems. Compass (Compass Education 2018) was built and launched in 2010 as a software-as-a-service solution for schools. Compass is distributed by JDLF International Pty Ltd. with offices in Victoria and San Francisco. Compass is the emerging leader in online school and student management in Australia, providing schools with immediate, on-demand access to a student’s performance, well-being, and much more. In late 2010, they launched CompassPay; their merchant service division focused on incorporating streamline payment options to parents and students. Hurstbridge Primary School does not take advantage of this facility at the moment (Fig. 5).

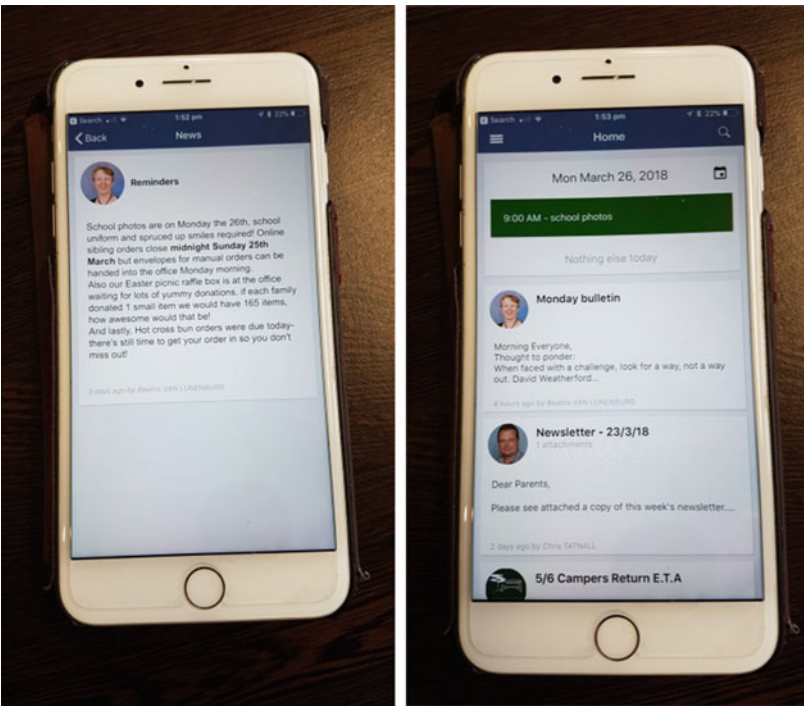
Compass assists with roll marking and attendance, semester and progress reporting, news feeds and calendars, staff student and parent

portals, online payments and consent, resource and curriculum building, parent-teacher interviews, well-being and behavior management, event planning, budgeting and purchases, smartphone application, SMS and push notifications, parent communication, and more.

In Hurstbridge Primary School, Compass is used for communicating with parents. Once rolls are marked on Compass using the teacher’s laptop, smartphone, or tablet, SMSs are sent automatically to all students not present. Parents are then required to log into the Parent Portal to notify the school why their child is not present that day. Compass also sends parents notifications for all students who visit the sick bay, informing them what happened and what the school has done. Parents will be sent notifications when their child is out of uniform, when their Individual Learning Plans are completed or their school reports are available. Teachers are able to easily contact parents via email or SMS; parents also easily email their teachers to ask questions through the Compass Parent Portal.

Compass’s news feed allows the school to share information, forms, letters, etc. with all

School Management Software in a Primary School in Victoria, Use of,
Fig. 5 Accessing Compass on a smart phone



parents easily. The internal news allows for communication between staff at the school. A daily bulletin is shared with all staff informing them of what is happening that day at the school.

Updating information in Compass is very important; each night the school's administration system, CASES21, will update parent, staff, and student data into Compass, ensuring that data is up to date and correct. Student attendance data collected on Compass as well as student academic achievement data is updated back into CASES21 to be shared with the Department of Education.

EduMail

This exchange email system is based on Microsoft Outlook. Each teacher has their own email address provided by the Department of Education. Bulletins are sent weekly from the Department of Education to school management which then uses the system to forward these to each individual teacher. The Department of Education does not normally contact individual teachers directly via EduMail. School management has access to the management side of EduMail for their own school.

Almost everyone, of course, now makes use of email whether they use it for work or at home, and Victorian teachers are no different. The system provides each teacher with their own email address, and in addition to these individual staff accounts, the school also has its own email account. While at one time in the past the Department of Education used to communicate with schools and teachers via "The Victorian Education Gazette" printed monthly, in more recent times, a summary weekly bulletin was provided by Fax, but now everything is sent to the school by email.

Conclusion

What difference to school management and to teachers have these new systems made at Hurstbridge Primary School? The answer is that they have made a great deal of difference. Very little administrative output is now handwritten. This has made a quite dramatic change in the

way that the school office operates and changed the roles and tasks of office staff. The old cash-books are gone, and there is now no need for office staff to count or balance cash: office staff jobs are very different. Much more access to data is now available, and reports can easily be generated for each subject budget (which was very difficult in the past) and for any other account. This provides more easily accessible information, to both teachers and school administrators. All accounts and bills are settled by electronic payment, and parents pay any school fees via BPAY (an electronic bill payment system widely used in Australia). This makes quite a difference in the parent-school interface.

Parent communication has become a lot more transparent. All notices and information between the school and home is done via Compass. For parents this one platform provides them with everything they need in one place. They can also contact the school, book parent-teacher interviews, enrol their children into clubs, etc. through the Parent Portal. For the school, it is important that this is kept up to date, creating a new role in the school for a Compass Manager. For the classroom teacher, having all the information about their students in one location has made it significantly easier for their daily teaching. Parents also have notices, school reports, Individual Learning Plans, etc. easily accessible online at any time.

Although not all are compulsory, these systems are necessary for a school to operate efficiently today, and their use makes life much easier in a busy school environment.

Cross-References

- ▶ [Attendance Records, Educational Management](#)
- ▶ [Decision Support Systems and Knowledge Management in Education](#)
- ▶ [Human, Social, and Ethical Aspects of Information Technology Management Systems](#)
- ▶ [Social Networks in Higher Education Management](#)
- ▶ [Support for School and Institutional Improvement and Accountability](#)

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Science Education

- Gender Difference in Self-Efficacy for Computational Thinking in K-12
- Science Education and Technology

Science Education and Technology

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Synonyms

Industrial revolution 4.0; Interdisciplinary science teaching; Science education; Science literacy; Technology

Introduction

The world today is confronted with many socio-scientific and technological issues. Presley et al. (2013) defined socio-scientific issues as open-ended social problems with substantive connections to science. Zeidler and Nichols (2009) considered them as controversial in nature that require a degree of moral reasoning or “the evaluation of ethical concerns in the process of arriving at

decisions regarding possible resolution of those issues.” Sadler (2004) indicated that such issues are personally meaningful, require the use of evidence-based reasoning, and provide a context for understanding scientific information. These issues include climate change, use of nuclear power and gene therapy, human cloning, and the production of genetically modified organisms.

On the other hand, technological issues have been associated with the development and use of certain forms of technology. The use of information and communication technologies (ICT), for instance, may put some social processes at risk. Although ICT has improved social processes such as banking, marketing, and health care, they have become very dependent on the use of information systems, which could not be made 100% secure. Audestad (2005 as cited in Werlinger, Hawkey, and Beznosov 2008) suggested that one of the reasons for this is the complexity of the technology. “This complexity makes it difficult for the decision makers to manage the big picture and design security policies that cover all the possible configurations of the systems” (Werlinger et al. 2008). Hence, security testing has become a lengthy, complex, and costly process (Jiwnani and Zolkowitz 2002). Other issues associated with technological use include environmental degradation, pollution, addiction, and risk to safety.

These and other scientific and technological developments give rise to myriad of ethical, moral, and global concerns that threaten human dignity and survival (Choi et al. 2011). These make them essential sociocultural decision points since they are not only threatening human survival but also transforming the world economy, encouraging new patterns of social mobility and migration, and increasing interconnectivity between and within societies and culture. As Choi et al. (2011) indicated, “these concerns stretch from the personal to societal and global.” Hazelkorn et al. (2015) argued that these developments are “placing new demands on governments, educational institutions, businesses and civil society organizations to meet the evolving needs of society and the workplace.” The concerns that resulted from them can be solved “through collaboration,

communication, and cooperation between people who see themselves as members of a global community” (Choi et al. 2011).

These concerns call for producing citizens who understand scientific ideas, intellectual capabilities, creativity, and reasoning (Choi et al. 2011). There is a need to “nurture citizens with an awareness and respect of the issues and problems that exist throughout the world so that they can make important environment, health, and social policy decisions for themselves and the global community” (Choi et al. 2011). Science education provides the key towards this goal and technology could provide a platform in achieving this goal. But, the current social and technological landscape necessitates a review as to how science education should be approached. This entry aims to elucidate on how science education can be taught given the myriad technological changes and innovations in recent years, how it should respond to these technological advances, and how to harness technology to achieve these goals.

Science Education: Achieving Scientific Literacy

Scientific literacy is the common goal of science education. Science education should produce people who can think scientifically, apply knowledge to practice, critically assess information, and actively engage in an informed democratic dialogue about socio-scientific issues using valid evidences and scientific tools for reasoning (Siarova et al. 2019). Being a society influenced by information and technology, knowledge of and about science is essential to preparing people to be active and responsible citizens who can work collaboratively and communicate clearly the complex challenges facing society. As Alberts (2009) indicated, the knowledge of and about science can help people explain and understand the natural world, guide technological development and innovation, and forecast and plan their future personal and societal success.

Science education provides the knowledge and process of knowing things systematically in the natural world. An effective science education

facilitates students' learning of both the content and methodology of science so that they are able to design and analyze empirical investigations or utilize empirical evidences in constructing and refining explanations of certain phenomena (National Research Council 2007). Hence, the National Research Council (2007) described students who are proficient in science as students who can:

- (a) Know, use, and interpret scientific explanations of the natural world
- (b) Generate and evaluate scientific evidence and explanations
- (c) Understand the nature and development of scientific knowledge
- (d) Participate productively in scientific practices and discourse

Harrison (1982) suggested similar outcomes of science education. For him, an effective science education must provide learning experiences that develop a student's ability to discover and explore scientific phenomena, rationalize results of investigations, understand the integrity of the scientific process and knowledge, and explore the impacts of scientific knowledge on the perception of one's self, community, and the environment. Moreover, he sees a scientifically proficient individual as one who participates critically in decision-making about societal matters involving science and technology and understands the place of probability and statistics in science and in the analysis and resolution of societal problems. These outcomes emphasize the significance of the learning process rather than overloading the academic experience of students with facts, which they would most likely just memorize (Harrison 1982). Thus, the approach to science education must allow students to achieve scientific literacy, which is commonly used as the reason for studying science in schools (Brown et al. 2005) although as Fensham (2004) has indicated, it has received different interpretations from different individuals or institutions.

Holbrook and Rannikmae (2009) cited two views of scientific literacy, one from the camp of

those that advocate a central role for the knowledge of science and another from those who see scientific literacy with societal usefulness. The first view is grounded on the idea that science has concepts that are essential and that its content is a crucial component in scientific literacy (Holbrook and Rannikmae 2009). Maienschein (1998) considered it as a short-term view of knowing science, where its focus is more on knowing and understanding scientific concepts rather than on the capacity of the students to use these concepts for social use.

On the other hand, the second view looks at scientific literacy as a requirement for adapting to the rapidly changing world. As Rychen and Salganik (2003) suggested, this view sees scientific literacy aligned with the development of life skills such as reasoning skills in a social context. It recognizes that scientific literacy has little to do with science teaching solely for a career in science (Holbrook and Rannikmae 2009) but with science teaching that addresses social needs. In fact, it contended that social needs must be a major consideration in putting scientific literacy as a goal of science education. Németh and Korom (2012) reported that this view has received increasingly more attention over the past few decades than the first one. In fact, Holbrook and Kannikmae (2009) indicated that this view has been utilized to refute the need for specialized science courses in school. They cited that specialist courses are simply extensions of the generalist courses with an increase of "time on task" for more in-depth investigations. Thus, Németh and Korom (2012) suggested that general science courses are sufficient to develop students' skills and competencies that enhance awareness of the natural sciences, ability to apply knowledge in everyday life, and capacity for learning independently, acquiring information, and making decisions.

Given the gravity of the need for scientific literacy, Fisk (2017) suggested that science education must assume a new vision, one that promotes learners not only to learn the skills and knowledge of and about science but also to identify the sources from which they would learn these

skills and knowledge. Yager (2015) also suggested that these skills must aid individuals to explore the natural universe and explain the objects and events encountered as well as increase their economic productivity. It should likewise correct students' perceptions that "doing" science is only listening, interpreting, recalling, and/or repeating what they are told (Yager 2015).

The current technological landscape is expected to facilitate the achievement of these goals. For instance, the development and advances of Internet technology make teaching and learning resources accessible and available to teachers anytime anywhere. Wiesenmayer and Koul (1998) reported that the Internet stores a vast array of teaching materials such as graphics, sound files, lesson plans, documents, data, and software that teachers can access and integrate into their lessons. The presence of these readily available resources is expected to support teaching and learning of science. Teaching can become effective when diverse resources are being provided and teachers can readily access them (Odunlade 2017). The availability and accessibility of these resources will not only broaden the teachers' knowledge base but also prepare them for the challenges that will come along the way as they impart knowledge to students (Odunlade 2017). In recent years, Recker et al. (2013) reported that there has been a tremendous growth in the number of available Internet-based learning objects for teaching and learning as more free online resources were uploaded on the Internet in response to the open educational resources (OER) movement. This movement has allowed the proliferation of educational repositories of rich media on the Internet that can be used or reused for instruction (Perez 2017). This unprecedented growth in information resources on the Internet is seen to improve the way science is being taught. As Kumari (1998) indicated, the use of information resources on the Internet could require teachers to rethink the way they teach and/or create their lessons (Kumari 1998), and in so doing, they would improve the way they deliver science content to students.

Responding to Recent Technological Innovations: The IR 4.0

The recent technological revolution labeled as the fourth industrial revolution or IR 4.0 has significantly changed the world economy, just as the first three revolutions did in the past. According to Azmi et al. (2018), these four revolutions influenced not only the production itself but the labor market and the educational system as well. Schwab (2016) considers IR 4.0 as an unavoidable change that will affect every line of business and system of production, management, and control in almost every country. Frezzo (2017) emphasized that with IR 4.0, technology will play a central role in nearly all aspects of the society including education. With its impacts on the production system, IR 4.0 will demand new sets of competencies from students. Azmi et al. (2018) indicated that the expectations of industries and job market are usually influenced by society, economy and competition, and revolutions of industry. It means that demanded skills will change according to the revolutions of industry, although some skills may remain unchanged but should be enhanced to complement the needs of today's industry (Azmi et al. 2018).

Petrillo et al. (2018) identified three fundamental aspects of IR 4.0. The first one is the digitization and increased integration of vertical and horizontal value chains. This includes the development of custom products, customer's digital orders, automatic data transfer, and integrated customer service systems (Petrillo et al. 2018). The second one is the digitization of produce and service offerings, which involves the complete description of the product and its related services through intelligence works. The third is the introduction of innovative digital business models where high levels of interaction between systems and technology opportunities develop new and integrated digital solutions (Petrillo et al. 2018). These aspects have radically transformed the traditional industries by changing their approach to the work, i.e., extensive use of new production technology, new machinery, new materials, and new inputs. As Petrillo et al. (2018)

have indicated, knowledge has become an essential input in this new industrial context.

On the other hand, Capgemini Consulting (2014) implied that IR 4.0 is characterized by the merging of real and virtual worlds in cyber-physical systems. It involves the collaboration of intelligent machines, storage systems, and production systems into intelligent networks (Capgemini Consulting 2014). According to Lee et al. (2014), the cyber-physical system consists of an IT system being integrated with mechanical and electronic components that are connected to online networks to allow the communication between machines in a similar way to social networks. The very purpose for such innovations is to make factories “smart,” so that they can produce customized products on an industrial scale. Likewise, it is intended to create operational flexibility and efficiency so that many opportunities for improvements may be provided (Lee et al. 2014).

How work is done in IR 4.0 necessitates the development of technologies that can support the industries’ operations. Petrillo et al. (2018) identified nine main technologies that play important roles in IR 4.0. These technologies include big data, cloud computing, cybersecurity, automated robots, additive manufacturing techniques and 3D printing, augmented reality, horizontal and vertical integration technology, and simulation systems and software. These technologies are essential tools for maximization of the benefits of IR 4.0. Cloud computing, for instance, “allows [one] to manage huge data volumes in open systems and ensure real-time communication for production systems” (Petrillo et al. 2018) and “access to information from anywhere in the world at any time, thus increasing flexibility” (Haiping et al. 2014). In addition, the additive manufacturing techniques and 3D printing make it possible to construct prototypes, which in turn, make it possible to test the material to be used for the finished products (Petrillo et al. 2018). Moreover, instead of the old paper manuals that are difficult to understand, augmented reality is used to educate operators for maintenance or machine set-up (Petrillo et al. 2018). On the other hand, simulation systems allow the simulation of business

systems and manufacturing processes, which are important in analyzing these under study.

Clearly, these technologies and the advances in industrial processes require different prerequisites for their applications and operations, respectively. As IR 4.0 is being controlled by artificial intelligence (AI) and digital physical frameworks that make human–machine interface more universal, Shahroom and Hussin (2018) suggested that education should be able to harness pertinent information and abilities that could not be replaced by robots. Education should be able to prepare graduates for future life and work given that production systems under IR 4.0 would now consist of cyber-physical systems that make decisions and monitor the physical processes of factories (Bolat and Bas 2018). It means that the curriculum designed by universities should be able to produce holistic graduates with technical and nontechnical skills and sound ethics and morality (Azmi et al. 2018).

In responding to these requirements, science educators and education managers should revisit the curriculum of science programs and the approach by which science courses are being taught. As previously presented, the curriculum of science programs should be redesigned to produce holistic graduates. Azmi et al. (2018) defined “holistic” to consist of both technical and nontechnical skills and good ethics and morality. As part of the redesigning of the curriculum, they suggested the inclusion of industrial training in the academic curriculum in higher education institutions. They argued that the inclusion of such training in the university curriculum can provide an opportunity for students to apply the knowledge they learn in the lecture to the real workplace in the industry. Renganathan et al. (2012) also indicated that industrial training allows students to incorporate their work-related experience and knowledge into their formal education. In this way, students would be able to gain confidence and face challenges at work and in universities as well as develop skills necessary for teamwork, working under pressure, and dealing with people from all levels of the organization that are important in their future workplace (Pillai et al. 2012). It is necessary that universities develop these skills

among their students because, as Prifti et al. (2017) had emphasized, these are the skills that new industries would be demanding. Aside from the technical skills such as those related to information technology or information system, employers expect graduates to be equipped with behavioral skills such as collaboration, negotiations, customer orientation, networking, and communication (Prifti et al. 2017).

In addition to the curricular revisions, how science is being taught should also be taken into consideration, given the changes in the educational and technological landscapes worldwide. As the new industrial structure operates under the framework of the Internet of Things or IOT, it is imperative that science and technology learners develop an interdisciplinary framework. Aside from science being an interdisciplinary field by nature, science teaching should consider using interdisciplinary approaches to appropriately prepare students for the new characteristics of the workplace.

The networked nature of the new workplace under IR 4.0 underscores the importance of approaching science education with an interdisciplinary framework both in its content and pedagogy. You (2017) has emphasized the importance of shifting the teaching paradigm towards interdisciplinary approaches. According to her, the various science standards across the globe have already reflected this shift. Haseeb (2018) emphasized that the new industrial landscape will be situated at the intersection of disciplines such as technical, business, and science. Hence, he suggested that universities should be able to come up with interdisciplinary programs to produce graduates with interdisciplinary perspectives. Although You (2017) argued that science as a discipline is already integrated and not isolated, Cone et al. (1998 as cited in You 2017) suggested that it should be taught through an interdisciplinary approach so that students would be able to develop an integrated understanding of the complexity of the natural system or its corresponding scientific problems. Having an integrated understanding of complex systems is important to survive in a highly networked working environment where every system is highly

interconnected with each other (Sony 2018). A singular discipline may not be able to provide such understanding of the complexity of this integrated system or the real world as a whole (You 2017). As previously indicated, science disciplines are already integrated and not isolated; hence, separating them may create an artificial way to teach science, one that is not reflective of its true nature (You 2017).

Interdisciplinary teaching is defined as a process where two or more subject areas are integrated to foster enhanced learning in each subject area (Cone et al. 2009). It emphasizes cooperative and collaborative learning (Stier et al. 1994) that facilitates student engagement. As networking and interconnectedness are focal components of the new industrial landscape (Petrillo et al. 2018), developing cooperative and collaborative skills among the students is an important preparation for students. Expectedly, workers in such workplaces will collaborate and communicate real time without borders with intelligent machines (Petrillo et al. 2018). Thus, it is important that students should be trained on these requirements.

In addition, as interdisciplinary teaching provides a variety of ways to learn that are appropriate to a discipline, it promotes active learning among the students (Kaittäni et al. 2016). Active learning could facilitate higher order thinking such as problem-solving, critical thinking, and metacognitive reflection (Jacobs 1989; Newell 1994). Leblanc (1998) described it as an approach engaged with the tenets of effective teaching and learning. The National Science Teachers Association (2003 as cited in Kaittäni, Derri, and Kioumourtzoglou 2016) defined higher order thinking as the ability of the students to engage effectively in inquiry using scientifically defensible methods. Again, these are important skills in working with increased complexity of the job contents, a characteristic of the new or future working environment (Petrillo et al. 2018).

Several empirical studies (e.g., Eggebrecht et al. 1996; Cone and Cone 2001; Lattuca et al. 2004; Derri et al. 2010; Mueller et al. 2014) show the effectiveness of interdisciplinary approaches in students' cognitive advancement

and improvement of affective domains. For instance, Coskun and Demirel (2010) reported that interdisciplinary projects contributed to the development of students' abilities to make "connections between previously learned concepts, transferring what has been learned, and using the computer effectively as well as development of problem-solving, logical thinking, and communication skills." Also, Akins and Akerson (2002) observed that students exposed to integrated projects for an electricity unit have high interest in the subject matter. The projects required the use of language, arts, and skills of oral and written communication to plan the projects, and application of science knowledge to build the most effective design. Carmichael and LaPierre (2014) reported that interdisciplinary learning and learning community practices are effective in "promoting academic improvement, retention, development of general education skills, and high levels of student engagement."

Given these advantages of using interdisciplinary approaches in science teaching, You (2017) suggested that integrating various disciplines in the teaching-learning processes in science education should help students "develop a general core of knowledge that is essential for deeper understanding and knowledge connections." Newell (1994) also suggested that interdisciplinary teaching could increase students' understanding of multiple perspectives, which is important in appreciating implications for ambiguity and diversity. The importance of interdisciplinary perspectives as Kaittani et al. (2016) had emphasized is its capacity to bring together expertise from different fields in a way that retains and clarifies the fundamental building blocks of a given discipline. The approach could help students see and understand the connect between and among concepts and principles across various disciplines while they build up their disciplinary knowledge.

You (2017) summarizes and explains the wide range of desirable educational benefits for students and teachers of the interdisciplinary approach. She identified four important points about the benefits of using interdisciplinary teaching in science education as follows:

1. Interdisciplinary understanding facilitates higher-order thinking.

Higher order thinking has been hailed as the hallmark of scientific literacy (National Science Teachers Association 2003). Deeper understanding and multiple perspectives of knowledge are reflections of higher order thinking. Several scholars proposed that the integration of disciplines could help students develop a general core of knowledge that is essential for deeper understanding and knowledge connections (You 2017). Newell (1994) highlighted that interdisciplinary learning could lead to deductive reasoning and synthetic thinking by students. Lattuca et al. (2004) referred to the interdisciplinary teaching outcomes as "assisting students in developing complex understanding in a particular subject area, promoting the development of sophisticated views of knowledge, building students' capacity to recognize, evaluate, and use differing perspectives, engaging student interest, increasing motivation, and enacting constructivist and active learning strategies."

2. Integrated knowledge expands the explanatory capacity of knowledge and provides the additional richness of viewing the topic through multiple lenses.

Interdisciplinary teaching approaches develop students' deep understanding of concepts in a variety of distinct contexts and cognitive processes, which in turn helps them create links between their disciplines and other disciplines. In an interdisciplinary teaching environment, students can become "motivated by realizing that a single way of knowing is insufficient to understand the complexity of the natural world" (You 2017). As You (2017) explained, this would allow them to actively develop their own interdisciplinary stance on all sciences and "to demonstrate the full range of their understanding of science."

Lake (1994) made a similar stance when she argued that learners in programs taught with an interdisciplinary approach are guided to a deeper assimilation of cross-disciplinary concepts. It means, for instance, that students in an interdisciplinary program are expected to

complete a critical analysis of the connections between the artistic expressions such as in visual arts, music, or poetry, and the philosophical and political thought characteristic of an era (Lake 1994).

3. Educational scholars have suggested that interdisciplinary connections may make “learning easier... more realistic and potentially more useful to the student.”

Students might easily make sense of scientific issues and problems when they are presented with knowledge in an interdisciplinary perspective. As Entwistle and Ramsden (1983) have suggested, students who took a deep approach to learning would “seek meaning, reflect on what has been learned, and internalize knowledge by creating personal understanding.” With the multiplicity of perspectives and frameworks in an interdisciplinary approach, students would develop skills and knowledge associated with any of the relevant disciplines that could aid them to cope with real-life issues (You 2017). In addition, “teaching practices with an interdisciplinary approach can help students make sense of science regarding abstract scientific concepts and the role and function of science in modern-day society, which can encourage them to hold a more holistic view of real-world phenomena” (Fogarty 1991).

4. Several studies have been attentive to affective gains made in interdisciplinary learning contexts.

Empirical evidences indicate that interdisciplinary teaching develops positive attitudes and motivation among students toward learning. For instance, Bragaw et al. (1995) confirmed that interdisciplinary teaching produced positive values on students’ attitudes and motivation for learning. Barab and Landa (1997) made a similar observation when they reported that interdisciplinary curriculum and instruction motivated students to develop problem-solving skills. This is important because, as Singh et al. (2005) had argued, the affective factors drive students to action, where they initiate and direct purposeful behavior for evaluating their progress toward their goal. They

also provide a driving force for students to alter their behavior, if necessary, to ensure success at their desired level (You 2017).

Technology for Science Education

The current technological innovations could be harnessed to improve the delivery, management, and assessment of science education. Isman et al. (2007) believed that technologies can enhance students’ deep understanding of scientific concepts by changing what is abstract to concrete to make them easier to understand. This ability of technologies should be given due importance by science teachers to provide a productive learning experience to students in science education. Jowallah (2008) indicated that the use of technology in science teaching could help improve students’ involvement in courses, assuring their progress as active learners, and/or widen their independency and social interaction.

Roblyer (2003) defined educational technology as a combination of processes and tools that are used to address educational needs and problems. Educational technology could consist of two components, namely, processes and resources although most people think of technology as just the products (Smaldino et al. 2005). The processes are simply the learning activities necessary to achieve the learning objectives of the course while the resources are the tools used to enhance learning (Isman et al. 2007). As Newby et al. (1996) indicated, technology performs a bridging function between the theoretical explorations on the one hand and the real-world problems on the other. Thus, educational technologists should be able to design and redesign technological tools to address this concern. In science education, educational technologists should “use research method, pay attention to theory, plan activities, implement theoretical knowledge, and evaluate the application results so that they would be able to re-design the technological tools to achieve the goals of science education” (Isman et al. 2007). Roblyer and Edwards (2000) reported that such technology as the Internet, hypermedia, and big data had

significantly advanced the goals of science education by providing students with readily accessible information anywhere, anytime. Linn (2003) also stressed that technological innovations aid in formulating and re-formulating science instruction, creating new fields, and exploring impacts of new technologies. For instance, the rapid advances in information and communication technology had shifted the content delivery paradigm from teacher-centered to learner-centered to learning-centered. This shift has made the science learning environment more collaborative and interactive, which effectively increased students' interest for learning (Isman et al. 2007). Suduc et al. (2011) described this change as the evolution "from the formal transmission of information to an active process of knowledge acquisition, based more on the studying and understanding of practical aspects of a process than learning of the involved theoretical concepts."

There are several technologies that have supported the development of science education through the years. For instance, the development of light microscopy in the early part of the nineteenth century has transformed the way plant and animal tissues are being understood. With the availability of enhanced light microscopes, all plant and animal tissues were discovered to be aggregates of individual cells. The discovery of cells then has formalized the beginning of cell biology (Alberts et al. 2002), which was marked with the development of the cell theory proposed by Schleiden and Schwann in 1838. Since then, there has been a better understanding of the microscopic world as scientists continue to explore and provide information about it (Storksdieck 2015). Such understanding was advanced with the invention of the electron microscope (EM) in 1931 by the physicist Ernst Ruska and the electrical engineer Max Knoll. Today, the various EM-mediated studies provide a better projection of the microscopic processes and structures as EM makes subcellular structures and processes visible. Thomas et al. (2015) considered these advances as influential in the development of molecular biology.

Telescopes have also improved knowledge about the universe. For instance, it was instrumental in changing the Ptolemaic geocentric (earth-centered) view of the universe to the Copernican heliocentric (sun-centered) view. The Galilean telescope provided astronomical information that refuted the geocentric worldview of Ptolemy and established the heliocentric worldview of Copernicus. Because of the availability of telescopes, Johannes Kepler wrote his "Astronomia Nova" where he introduced the concept of planetary motion for the Solar System. Such work in 1609 has revolutionized the field of astronomy (Brown 2016). Since then, the use of telescopes in astronomical observations has increasingly become the norm. Today, a variety of telescopes are utilized to collect immense quantities of astronomical data that refine or refute the current understanding of outer space structures and processes. Robotic or remote telescopes are used to collect data about exoplanets or planets beyond the earth's solar system (Howell 2018). Among the discovered exoplanets so far, 51 Pegasi b, HD 209458 b, 55 Cancri e, HD 80606 b, and WASP-33b could provide information that could expand students' perspectives on how planets form and evolve (Howell 2018).

Recently, the rapid advances in ICT and its combination with other technologies have advanced scientific knowledge and processes. It also widens access to both the information generated through scientific processes and science education itself. It has made science education more inclusive, more attractive, and far-reaching, which is important in enhancing the scientific literacy of every individual in a society. As Suduc et al. (2011) emphasized, "the use of ICT in science education offers even more advantages due to the attractive premises to simulate and interactively explore and test experiments which would be too expensive or too dangerous in real settings (for example in nuclear physics)."

The combination of ICTs with microscopy has improved knowledge on biological processes at the gene level. Swedlow (2012) reported that combining the technical advances in microscopy with robotics has resulted in the development of

automated microscopes suitable for studying gene transcription. Using this technology, better information about gene action and its practical application has been obtained. As Swedlow (2012) reported, these microscopes are capable of recording cell phenotypes that result from systematic gene knockdown by RNA interference (RNAi). This information has allowed the development of RNAi technology that is used to screen drugs. Through RNAi technology, genes that can confer drug resistance or whose mutant phenotypes are ameliorated by drug treatment could easily be identified (Agrawal et al. 2003).

In relation to science teaching, ICT can be harnessed to support the administrative teaching tasks and the teaching and learning processes in a classroom (Tondeur et al. 2007). ICT can be utilized to support student administration, preparing worksheets, developing evaluation activities, keeping track of pupils' learning progress, etc. (Suduc et al. 2011). It can also be tapped to support and enhance the actual teaching and learning process (Tondeur et al. 2007). This could include the use of computers for demonstration purposes, drill and practice activities, modeling, representation of complex knowledge elements, discussions, collaboration, project work, etc. (Sang et al. 2010).

There are different ICTs that can be used to support science teaching and learning, and students should be able to construct their knowledge with activities supported by these technologies to enable them to become active in their courses (Balim et al. 2011). One of the technologies that is currently being implemented and continuously being studied for its application in education is artificial intelligence (AI). Reports (e.g., Popenici and Kerr 2017; Chassignol et al. 2018) have indicated that the use of artificial intelligence in science teaching has improved assessment and detection of learning and teaching gaps. With intelligent systems, assessing large numbers of assignments and detecting teaching and learning gaps are no longer a problem (Chassignol et al. 2018) albeit it might not be always true in all situations with no human interventions. In addition, the use of intelligent tutoring systems is

reported to increase productivity inside and outside a classroom (Chassignol et al. 2018). For students with learning difficulties, the use of AI helps them study more effectively and adapt to educational content through more individualized study plans. Individualized study plans are expected to address the differing students' pace of learning and understanding of instructions. Such differing pace could make students who are already ahead of the material easily bored, while others may be completely lost in new terms and phenomena (Chassignol et al. 2018). The capacity of AI to develop a more personalized learning environment could help resolve these issues.

The advancements of AI have also been tapped to create an inclusive science learning environment, where students who are physically challenged could still maximize their learning process. Assistive technologies such as text-to-speech, speech-to-text, zoom capacity, predictive text, spell checkers, and the like are some of the examples of technologies that are initially designed to assist people with disability (Popenici and Kerr 2017) though later their use has been expanded even to individuals who have no disabilities. Today, these technologies have augmented the learning interactions of students globally and can maximize their learning experiences. But it should be emphasized that although AI has enhanced teaching and learning processes, it cannot completely replace the roles of human teachers with students. In fact, Popenici and Kerr (2017) argued that despite the rapid advancements in AI, solely relying on these technologies for science teaching and learning is a dangerous path.

Augmented and virtual realities (A/VR) have also shown great potentials in enhancing science education. Furness et al. (1997) reported that the use of VR improves learning by providing the learners an experience of a phenomenon they could not have experienced before, either in direct interaction with the real world or using other technologies. On the other hand, Wu et al. (2013) reported that augmented reality systems support the visualization of abstract science concepts or unobservable phenomena, and have noted such affordances as learning content in 3D

perspective, ubiquitous, collaborative, and situated learning, immediacy, and immersion, bridging the formal and informal learning and visualizing the invisible in using it. Munnerley et al. (2012) reported similar observations. They emphasized that AR provides opportunities in relation to visualization, mobility, alternative perspectives, and comparison of multiple perspectives. Radu (2014) argued that allowing students to physically enact the abstract educational concepts through gestures, etc. will greatly increase their understanding of the concepts.

The Internet also plays important roles in teaching science such as in facilitating productive interactions, seeking new information, and aiding in research, dissemination of information, and extension of classroom instruction (Haury and Milbourne 1999). With Internet-based communication tools, teachers can extend their productive interactions with their students and others around the globe, especially those that share their interests (Haury and Milbourne 1999). This is a way by which students' interests in science could be maintained. In addition, being a storage of diverse learning materials, the Internet can help facilitate students' learning of new concepts and/or making of plans for a scientific project (Haury and Milbourne 1999). Indeed, ideas that could lead to the formulation of research questions may be searched from the Internet.

The capacity of the Internet to extend classroom instruction has gained popularity in the last two decades. Modalities of content delivery such as online learning or blended learning receive considerable attention from the academe as well as corporate institutions. Such extensions of instruction have widened access to science education. Renes (2015) mentioned that e-Learning in higher education has reached populations that were not commonly reached by the traditional modality. These populations include students with disabilities (Kumar et al. 2011), rural students who have difficulty relocating (de la Varre et al. 2010), parents with children (Mueller 2008), military personnel (Star-Glass 2011), and working individuals (Serrat 2010).

Although these technologies have contributed so much in the development of science education,

how effective they are for science teaching and learning depends on the properties of the tool itself, users' technological and pedagogical orientation, teachers' beliefs about the suitability of the tool, and the available support. As Salihi (2015) has emphasized, an effective use of a technology cannot be analyzed without the knowledge of the users of the tool or the context in which such a tool is being used. These factors should be considered to make science education effective in reaching its goal of increasing the scientific literacy of every society.

Concluding Remarks

Science education is playing an important role in societal development. It allows the development of individuals' abilities to creatively utilize appropriate empirically based scientific knowledge and skills that are relevant to their daily life and are useful in making socio-scientific decisions. Being a society influenced by information and technology, these knowledge and skills are essential in preparing people to be active and responsible citizens of a country.

Science education is continuously evolving, and in each evolution, technology plays an important role not only in terms of transforming its curriculum, delivery, and management but also in transforming its practitioners and learners. The rapid advances in technology, especially in ICTs, have transformed science teaching and learning, from highly teacher-centered to authentic learner-centered to learning-centered. Consequently, teachers under the new approach become more and more facilitators of learning and are expected to make learning more collaborative, personalized, and networked. This is necessary to prepare students for the challenges brought about by IR 4.0.

As the interaction of science education and technology has been proven to be essential in nation building, it is therefore imperative that a country develops its technological roadmaps. These roadmaps should direct its educational reformation to better address the current as well as future societal and industrial demands.

Cross-References

- [Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools](#)
- [Assisting Students with Intellectual Disability Through Technology](#)
- [Assistive Technology and the Gifted Learner](#)
- [Augmented Reality and Its Use in Education](#)
- [Blended Learning](#)
- [Computer-Assisted Learning](#)
- [Computational Thinking](#)
- [Teacher Education, Thinking About ICT](#)
- [Technological Innovation in ICT for Education](#)

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Science Literacy

- Science Education and Technology

Screen Access

- Assisting People with Vision Impairments Through Technology

Screen-Based Simulator

- Digital Simulations in Healthcare Education

Scrum

- Agile Methodology in Education of IT Students, Application of

Seamless Learning

- Mobile Learning, Challenges in

Secondary Schools

- Beginnings of Computing in School Education in Australia

Security and Privacy of Information Technology Management Systems

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Synonyms

Data protection

Definition

Information security is usually defined as a feature of information systems management which involves three main aspects, named confidentiality, integrity, and availability (Lov om behandling 2000; ISO/IEC 27002:2005 2005; ISO/IEC 27000:2009 2009). Usually, quality is included as a fourth aspect of information security, although it can be considered as overlapping with integrity. The following is a brief definition of these items: (a) Confidentiality is the guarantee that information is not made available or disclosed to unauthorized persons, entities, or processes; (b) integrity relates to the trustworthiness of the information, thus assuring that data has not been deliberately tampered with, nor accidentally changed; (c) availability means that information is accessible and can be utilized upon demand by an authorized entity; and (d) quality refers to the information being correct and not misleading. Among the aforementioned aspects, confidentiality is particularly important because of the sensitivity of personal information. Associated with security, privacy emerges as an issue because of the right to privacy with respect to the processing of personal data. In this way, regarding the relationship between security and privacy, the latter could be defined as the right of the client and the former the duty of the service provider (Henriksen et al. 2013).

Security

Introduction

The security of information technology (IT) is a matter of great importance for organizations. One important reason is the continued use of IT by different stakeholders and the large amount of information stored, sometimes critical to the organization or its customers. Education centers are not oblivious to this type of problem, with the main characteristic being that the clients, in this case, are the students who study at the center, and the sensitive information is of a mainly personal

nature (Culhane et al. 2018). Thus, the management of education centers is faced with a problem for which they are responsible as top management of the organization but for which they have often not received training. Many of the aspects related to the assurance of information security are fundamentally based on technical issues, with which many school directors feel uncomfortable. However, this lack of knowledge or discomfort cannot be a pretext for neglecting this important aspect of the management of information systems (Weng and Tang 2014). The directors and top managers of education centers and institutions must be aware of the implications of guaranteeing the security and privacy of the information they are responsible for as leaders of their organizations.

Education centers, regardless of the level of education they provide (primary, secondary, or higher education), which utilize information technology (IT) infrastructure must guarantee its normal functioning, especially when a large part of their daily operations is based on the use of information systems and technologies. Errors and cyberattacks, both internal and external, can prevent its proper functioning. For this reason, it is crucial to have a security policy that includes actions to prevent errors or attacks from affecting the technological infrastructure. However, this policy should not be considered as optional since there are issues related to the safeguarding of privacy which are protected by law. Therefore, this issue becomes a mandatory element in the agenda of decisions and activities of those responsible for education centers and institutions (Brockmeier et al. 2005). In addition, the problems that education centers encounter in this area, although in many cases they are public, non-profit institutions, are the same as those faced by companies and organizations of all kinds that make use of information systems and technologies as part of their daily activities. The above is, however, an opportunity for schools because advantage can be taken of the great volume of knowledge generated in terms of the security and privacy of information systems and technologies in the business field.

The main aspects that should be considered in terms of the security of information systems within any organization, and therefore in educational organizations, are the following (CAP Gemini 2000): (i) errors due to a malfunction of hardware or software, (ii) errors due to IT users, (iii) natural catastrophes, (iv) unauthorized access by external or internal personnel, (v) deliberate damage done by staff or by strangers, and (vi) deterioration due to aging or everyday use of infrastructure.

Policies and Procedures

Establishing policies and procedures related to the security of the IT infrastructure is a key issue that managers of any type of organization must face. The significance of this issue increases in environments where computers are connected through communication networks, whether internal or external. In this situation, to the physical threats are added the risks that arise through communications, either in the form of unauthorized deliberate access or by the introduction of harmful software (viruses) into the system.

Each organization should establish a security policy and communicate it to all staff. The policy should be the result of an analysis of the potential risks to which the organization may be exposed. The purpose is to protect the assets of the organization, in this case, data and information about the different stakeholders of the education centers; for this objective, the collaboration of those affected should be encouraged, i.e., teachers, administrators and technicians, as well as parents and students. The security measures must be coherent, and a key factor in obtaining the commitment to execute security procedures is to make them practicable. The people involved will most likely not accept procedures that make their work practically impossible and, if this were the case, in all likelihood they would end up using their time and ingenuity to bypass such controls. Therefore, impractical conditions raise the risks instead of decreasing them. The IT infrastructure cannot be protected by technical means alone; it is also necessary to have a security plan with the guarantee that people involved in IT are aware of and act

to adhere to the general security policy (Culhane et al. 2018).

The responsibility for security matters rests with the management of the center and, in the case of delegation, the person in charge of the IT department, assuming there is one. The responsibilities that are acquired include (i) the prohibition of the use of unauthorized software, (ii) the implementation of the physical security process, (iii) the availability of procedures that prevent unauthorized access to the center's IT systems, and (iv) responsibility for the integrity of the data. One of the most important missions of the IT infrastructure security manager is to raise security awareness in all stakeholders. This is because success in this matter depends on procedures being followed, and this is only possible when there is full awareness. For this to be achieved, a culture of security must be created, which can be materialized through campaigns based on messages and information on this issue. The staff of the center in direct contact with IT must be the first recipients of this type of message, in which the need to protect the information and the IT infrastructure used in the center must be highlighted, as it is part of their work routine and, therefore, fundamental to the correct development of teaching tasks.

A very useful tool for checking the security of the IT infrastructure at the center consists of the regular practice of auditing the procedures and their level of effectiveness in terms of computer security. Essential aspects to evaluate as part of the audit include (CAP Gemini 2000) (i) access controls to the IT systems, (ii) physical access controls to the facilities in which the electronic devices are located, (iii) protection against physical threats, (iv) data integrity controls, (v) generation of backup copies, and (vi) security awareness procedures. The following is a set of factors recommended for consideration in defining security procedures. They cover a wide range of cases, and it must be the director or head of security of the center who establishes the degree of development of each one of them (for a greater development of the concepts, it is recommended to go to a computer security manual published by consultants or IT manufacturers).

Physical security. The protection of the IT infrastructure depends on the physical conditions in which computer systems and communication networks operate. There are also other risks, such as fire and flood, that are beyond the physical characteristics of the IT infrastructure, but that need to be considered. The storage of documentation and magnetic supports deserve special mention due to the importance of ensuring their protection. Aspects to take into consideration related to physical security are electrical protection, fire risks, natural catastrophes, urban disorders, and buildings and facilities outside the center susceptible to generating hazards (gas stations, bus stations, high density traffic routes, railways, etc.).

Physical access. One way to ensure security is by restricting access to the room in which sensitive equipment is located, such as servers or communication racks. Access to this equipment allows control over the system, so protocols should be established to prevent unauthorized personnel from accessing the equipment. Access by authorized personnel should also be monitored. Aspects to take into consideration related to physical access are security controls in the areas of access to sensitive equipment, the use of booths or security boxes to store documentation and magnetic backup media, and security keys and protocols for control of access for both internal and external personnel (maintenance technicians).

Access to computer applications. Access by an unauthorized person to the information systems housed in an education center is a crime, and, as such, those who commit it can be reported and prosecuted. However, education center managers must articulate policies and procedures, directly or through specialized technical services, internal or external, to protect the IT infrastructure from unauthorized access. The nature of the information available in the center's databases and applications, and the possibility of accessing them through internal and external networks, makes this a critical point of IT security. The main requirement is to develop mechanisms

that ensure that only authorized users can access computer systems with user identifiers and defined passwords. The first, identifiers, constitute a main component of computer security. It should apply to both people and terminals. Each user must have an identifier to control their access rights, privileges, available resources, and access to sensitive information. For this reason, user identifiers must be assigned individually. The second key mechanism to ensure that no unauthorized person accesses the information systems of the center is the use of passwords. As far as this question is concerned, a password policy should be established, known to the users of the systems, which includes the characteristics of the password itself (length, type of characters) and the duration of its validity.

Installation of unauthorized software. The installation and use of unauthorized software pose many risks, both for potential infringement of intellectual property rights and for facilitating security breaches. Many unauthorized downloads come from internal personnel or from the organization's suppliers of IT equipment. It is often the case that the staff of education centers, whether due to dissatisfaction, boredom, or other reasons, add their own software to compulsory use programs for purposes unrelated to the requirements of their work. This software can lead to easy entry into sensitive parts of the information system, unauthorized operations (e.g., Trojan horses), or the installation of computer viruses into the center's systems. Installation of unlicensed software can damage the reputation of the organization if it is made public that this type of software is being used. The center can only be protected against such threats when users only make copies of the licensed software or obtain copies from external sources through control procedures. All users' computers should be audited and clear guidelines must be set to establish exactly which software applications can be approved for installation.

Network security. The systems are usually connected through communication networks,

both internal and external through the Internet, which generate threats to security. The risk comes from, among other sources, unauthorized access from outside and the installation of malicious software that may negatively affect the proper functioning of the IT infrastructure. The use of encryption systems, passwords, and advanced authentication systems through digital signature, firewalls, antivirus programs, etc. can decrease, although not avoid entirely, the potential risks derived from the use of communication networks. One of the least known forms of risk regarding the use of networks, especially the Internet, is the infringement of intellectual property. This could be the case regarding the information shown on the education center's official website. In this sense, part of the information present on the website may come from sources that are the intellectual property of third parties. On the other hand, there may be teachers or staff from the center who use material obtained on the Internet with registered copyrights. In this sense, it is important that all members of the organization become aware of the potential dangers of violating intellectual property laws, in addition to those mentioned above on safety.

Privacy

Definition

Privacy in the field of IT is understood as limiting the use of information systems to guarantee the honor and personal and family privacy of citizens and the full exercising of their rights (Schwartz 2004). Under this definition, of a broad nature, some related aspects can be circumscribed, such as (i) personal data, referring to all information about an identified or identifiable person, that is, whose identity can be determined directly or indirectly; (ii) processing of personal data, which is any operation or set of operations carried out (or not) by automated procedures and applied to personal data, such as collection, registration, modification, consultation, communication, suppression, or destruction; and (iii) personal data

file, i.e., a structured set of accessible personal data according to certain criteria, whether centralized or decentralized.

Introduction

The use of modern means of information processing and communication, with a huge capacity to process information of all kinds, has given rise to a growing concern for the security of IT infrastructure, mainly because of the damage that can be caused to the functioning of the organization derived from fraudulent access or use. However, it should not be forgotten that much of the information that is stored in the information systems is personal, that is, it affects personal privacy and the freedom to make decisions regarding the automation and transmission of personal data. Therefore, the security of IT infrastructure and privacy are two closely related areas, and each must be considered as complementary to the other in the management of IT. For the specific case of education centers, it is a function of educational management teams to ensure that not only are security policies and procedures established, but also that compliance with privacy requirements is ensured, given that there are numerous laws that establish compliance with minimum requirements which, if not met, is considered a crime.

Privacy or data protection is an issue that has acquired a high profile as a consequence of the continuous development of information processing systems, as well as the transmission of information through all types of networks. The right to personal privacy, which can easily be violated through these devices, has led to growing interest. This issue has been, for a long time, the remit of the courts, materializing in a series of national or supranational laws on the protection of the privacy of individuals' information. For educational managers, this question is of great importance because in schools there is a very sensitive group, namely, students. A large amount of personal or other information (academic, attitudinal, aptitude) is handled by these organizations, and irresponsible use of it is not only subject to sanctions but can also cause great moral damage. When dealing with information

about minors in the case of schools, these considerations are all the more critical.

The set of terms and procedures related to privacy acquires special relevance in the figure of the controller, which is the person or public authority responsible for determining the purposes and means of processing personal data. Educational management teams have, therefore, the maximum responsibility in this matter and are in charge of establishing the procedures and policies that have to be communicated to all the members of the organization for compliance with the privacy directives (Akbaba-Altun and Güler 2008).

Legal Basis

Electronic communication and the storage of personal information are subject to national legislation and, in some cases, such as with European legislation, to supranational legislation. Examples of this are the EU directive on the processing of personal data for the countries of the European Union (Directive 95/46/EC 1995) and the Health Insurance Portability and Accountability Act of 1996 (HIPAA) in the United States (Health Insurance Portability and Accountability Act 1996). Standardized procedures compiled as international ISO standards on best practices for the establishment of information security techniques and IT have also been developed (ISO/IEC 27002:2005 2005; ISO/IEC 27000:2009 2009).

Recommended Actions for Managing the Privacy of Information in Educational Environments

The work of the management consists, first of all, of establishing the necessary technical and organizational measures that must be implemented for personal data files, equipment, and information systems, as well as ensuring that the people who intervene in the processing of this data comply with the privacy requirements as established by law. The recommendations established in the ISO standards on information technology security techniques are also useful for this function. The person in charge of the treatment of information is the director of the educational center, who, in the

case that they need support for these functions, can formally delegate the function of coordinating and controlling the required security and privacy measures (Wilk 2016). The following is a summary of recommended actions:

Security document. A first action in this matter is the development and implementation of security regulations to ensure the privacy of information. This is done through a mandatory document for staff with access to automated personal data and information systems. Said document should contain the following aspects: (i) scope of application, with detailed specification of the protected resources (automated data files, equipment, systems, programs, people intervening at some stage of the process); (ii) standards and procedures to guarantee the required level of security; (iii) staff functions and obligations; (iv) structure of the files with personal data and description of the information systems that treat them; (v) procedure for notification, management, and response to incidents; and (vi) procedures for making backup copies and for data recovery. The document must be updated and revised whenever there are relevant changes to the information system or to the organization thereof. Its content must be adapted at all times to the current legal provisions regarding the security of personal data.

Functions and obligations of the staff. The functions and obligations of each person with access to personal data and information systems will be clearly defined and documented. The personnel must know the safety regulations that affect the performance of their functions, as well as the consequences that could be incurred in case of non-compliance.

Incident registration. The notification and incident management procedure will necessarily contain a record stating the type of incident, the time it occurred, the person making the change, who is notified, and the effects that would have been derived.

Identification and authentication. The personal data security officer will ensure that there is an updated list of users who have authorized

access to the information system and establish identification and authentication procedures for said process.

Access control. The users will have authorized access only to the data and resources that they need for the development of their functions. In this sense, within the scope of teaching activities, teachers should be prevented from accessing sensitive personal data if it is not for a justified reason that affects the exercising of their teaching duties, in which case it will have to be done through a formal request. The information handled by teachers, in general terms, must be of an academic nature. Similarly, the administration staff, who habitually work with the personal data of students and their families, should have some kind of restriction on access to academic performance data. The officer responsible for the file will establish mechanisms to prevent a user from accessing data or resources with rights other than those authorized.

Management of data storage devices. The electronic devices that contain personal data must be able to identify the type of information they contain and be inventoried and stored in a place with access restricted to the personnel authorized as set in the security document. The movement of electronic devices that contain personal data outside the premises in which they are stored may only be authorized by the person responsible for the file.

Backup copies. A procedure for making backup copies and recovering data must be established. These procedures must guarantee their reconstruction in the state in which they were at the time of the loss or destruction. Backup copies should be scheduled periodically, at intervals that depend on the volume of updated data.

Summary

The right to information privacy and the security of the IT infrastructure is a matter of great importance that, however, has not traditionally received enough prominence in the agenda of educational

managers. Among the set of functions assigned to educational managers are also included those involved in information management and IT. Education centers generate and store a large amount of personal information, which can have negative implications for people's lives if they are misused. The laws on data protection and the right to privacy oblige educational managers to establish security protocols to safeguard people's right to privacy. For this reason, educational managers must assume this responsibility as part of their work. For this, they can rely on qualified personnel and on the wide range of recommendations and guides developed by national and international companies and organizations on information security and IT infrastructure. Each education center, according to its circumstances, must elaborate and comply with a security policy which is known to all the people who work at or have a relationship with the center and which includes coherent and practicable security measures.

Cross-References

- [Human, Social, and Ethical Aspects of Information Technology Management Systems](#)

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Shared Regulation

► [Shared Regulatory Planning in Minecraft](#)

Shared Regulatory Planning in Minecraft

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Synonyms

[Co-regulation](#); [Digital games-based learning](#); [Shared regulation](#); [Social regulation](#)

Introduction

Very few digital games can be described as a cultural phenomenon. From players that identify as “gamers,” extending a sphere of influence to anyone with a passing interest in mainstream popular culture (Thompson 2016), it is remarkable to consider how the independently developed game, Minecraft made its impact on mainstream popular culture. One of the key reasons often attributed to this success was its accessibility to a range of audiences and the affordances that it provided users to “play the game” in the manner of their preference (Zolyomi and Schmalz 2017). Minecraft is the rare game that can be almost all things to all players. It was designed to be shared.

While Minecraft can be played as a single player experience, it was most popular as a

multiplayer, online game (Zolyomi and Schmalz 2017; Thompson 2016). The increased interactions and socialization between players have inevitably contributed to increasingly sophisticated instances of social interaction, and this is an area that has received increasing academic attention. Research has been undertaken into the different forms of collaboration between players engaged in multiplayer games, particularly in relation to massively multiplayer online role-playing games such as World of Warcraft (Uz and Cagiltay 2015; Chen 2012). A key social skill for successful collaboration is social regulation, which can be thought of as the processes for controlling behavior within group interactions. This encyclopedia entry unpacks the concept of regulatory planning, a key process within an established conceptualization of social regulation (Grau and Whitebread 2012), illustrated using two different modes of multiplayer play in Minecraft.

Viewing Minecraft as a Tool for Collaborative Creation

Minecraft was originally conceived by its developers as a simplistic sandbox game, where a player would freely create, locate, and destroy objects called blocks. This form was known as a “Creative Mode,” which presents an open-ended space with no specific objectives or ending. The subsequent “Survival Mode” was soon released, a mode of play that encouraged players to mine resources and construct fortifications to withstand the damaging advances of “creeps,” or challenging hordes of creatures. As Minecraft began to transcend its origins as a niche independent game project and became a mainstream cultural phenomenon, many game players focused their output almost exclusively on building, sharing, and showcasing their creative designs. The addition of more sophisticated design components in subsequent updates to the game allowed players to add functions and automated macros to the static environment. Minecraft was coded in the platform agnostic computer language Java that encouraged players to contribute and share their own content. The affordances offered by these additions allowed the

design of automatic doors, context-dependent lighting, and the creation of complex mechanical components such as pistons.

Minecraft has been used as a research tool for exploring understandings of such diverse domains as spatial geometry (Foerster 2017), sustainable planning (West and Bleiberg 2013), digital storytelling (Garcia Martinez 2014), social skills (Petrov 2014), informatics (Wagner 2015), computer art application (Garcia Martinez 2014), project management (Saito Takebayashi and Yamaura 2014), and chemistry (Hanc1 2012) and artificial intelligence (Aluru et al. 2015).

The ongoing cycles of design modification and changing player behavior have resulted in Minecraft evolving into a more complex space for collaborative creativity and expression. The release of a server-based multiplayer feature made it possible for many players to work together, or against each other, with an online environment that appeared almost boundless. In a virtual gaming environment with a creative mode such as Minecraft, when players interact and collaborate, then they will consequently plan and regulate their behavior while negotiating, setting goals, and developing sub-games.

Conceptualizing and Capturing Instances of Self and Social Regulation

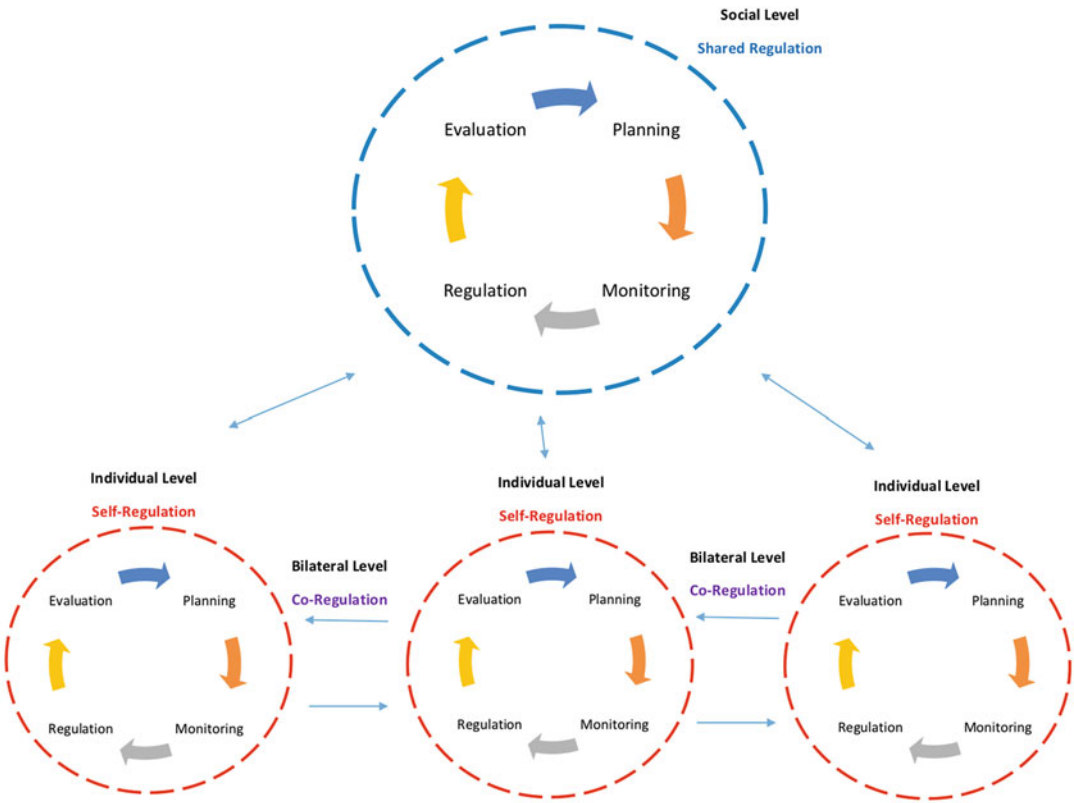
There has been a shift in the thought surrounding how regulations of cognitive and metacognitive processes in learners are understood, particularly in the field of educational psychology. Regulation has traditionally been described as a process at the individual level, contained to the “self,” with a focus on the child’s own cognitions, emotions, and behaviors (Hadwin et al. 2011). There has been a move away in the literature from such models of self-regulation towards a social understanding of an interplay between regulation at an individual level and a co-constructed social level (Hadwin et al. 2011; Volet et al. 2009; Vauras et al. 2003). These theorists no longer conceptualize students as isolated silos. This shift reflects the emergence of a sociocultural model of cognitive development, emphasizing the essentially social

nature of learning. This increased emphasis on social learning, particularly in regards to collaborative problem-solving, has resulted in new models to explain the regulation of individuals within these group contexts that exist outside of the boundaries of self-regulation.

- *Co-regulation* is a regulatory process that is intended to influence the “cognition, motivation or behavior of one specific member” of a group (Grau and Whitebread 2012, p. 411). This can be seen through the lens of a master-apprentice relationship or expert-novice tutoring relationship, where a “more knowledgeable other” guides a relatively less knowledgeable or skilled individual in solving an equation, or finding the right note on a musical instrument.
- *Shared regulation* is a regulatory process that is “more related to group planning, monitoring and regulation” of a shared activity, characterized by multiple group members interacting with each other to achieve a common goal (Grau and Whitebread 2012, p. 411). Despite this commonality of purpose, this form of regulation may still retain imbalances between participants in relative knowledge, skills, and social capital (Hadwin et al. 2011).

Grau and Whitebread (2012) discuss the interplay between these three forms of regulation, contending that all three are active, often simultaneously, in the collaborative planning, monitoring, regulation, and evaluation of group activities. Figure 1 visually represents the relationships between self-regulation at an individual process, co-regulation as a bilateral process, and shared regulation as a socially constructed co-process occurring during multilateral interactions. The focus is on the social levels of regulation, “co-regulation” and “shared regulation.”

As can be seen in Fig. 1, both self and social levels of regulation are conceptualized as consisting of four subprocesses spanning the planning, regulating, monitoring, and evaluation of behaviors. Focusing just on the shared planning processes within this model, Table 1 examines planning processes in three different contexts: planning the completion of a common task, planning the



Shared Regulatory Planning in Minecraft, Fig. 1 A visual representation of the self and social levels of regulation, as described by Grau and Whitebread (2012)

Shared Regulatory Planning in Minecraft, Table 1 Describing the planning processes within joint activities, as listed in the model by Grau and Whitebread (2012)

	Planning processes
Task	Planning the task
Indicative behaviors (<i>What does this look and sound like?</i>)	Talks about the relevant content knowledge that should be applied in the resolution of the task Talks about his/her knowledge about strategies or personal resources that can be used in order to solve the task Talks about setting goals Establish task-specific goals that can be used to guide cognition and monitoring Formulates a step-by-step strategy before solving a problem Propose a way of solving the task or a way to start doing it
Organizational	Planning the organization of the group
Indicative behaviors (<i>What does this look and sound like?</i>)	Students plan the organization of the task in a pragmatic level (who is going to do what)
Socio-emotional	Planning socio-emotional interactions
Indicative behaviors (<i>What does this look and sound like?</i>)	None provided as Grau and Whitebread reported they did not observe any instances of socio-emotional planning

organizational structure of the group, and planning the socio-emotional components of the interactions.

The use of this established model serves dual overarching purposes in helping to understand shared regulatory planning:

1. It provides a framework to capture and explore instances of social regulation in collaborative play in player created artifacts within the Minecraft community.
2. It allows for the exploration of the boundaries and tensions within Grau and Whitebread's (2012) when applied to a virtual environment.

Recording video and audio has been used as a tool for capturing a time and place, affording the identification of shared regulation with Science classrooms (Grau and Whitebread 2012) and exploring social regulation through the analysis of publicly shared footage from multiplayer Minecraft games (Harrison et al. 2018). Self-regulation is notoriously difficult to observe during a solo activity and a challenge to capture, relying on recording "self-talk" during a solo activity or asking the player to reflect or comment on their own performance. By contrast, in Minecraft, there are clearly identifiable instances when a player regulates their social behavior while planning, either as co-regulation with another player or shared regulation between multiple players. Instances of regulatory processes during joint activities have been observed by analyzing verbal and nonverbal communication between participants (Whitebread et al. 2009).

Exploring Shared Regulatory Planning in Minecraft

As is now increasingly common within gaming culture, Minecraft players and users often capture and share a recording of their game session using screen capturing software to stream live or publish the session to a video sharing service. These public recordings and gameplay artifacts are freely shared online. Not only do these invite feedback and comment but also they are a cyber-ethnographic opportunity to examine the community and culture created through computer-mediated social interaction.

The accompanying player narration is often deeply personal and may widely vary in style and nature from shared laughter, dialogue with other plays, to that colored by profanities or filled with obscure jargon. Players within the view of each other can draw attention or emphasize something by moving in unusual ways such as wildly jumping on the spot or gesturing. Another, albeit slower option is to type and broadcast a text message to other players. While online games are rich in visual images and audio messages, the option for feedback by nonverbal communication is limited. Despite this limitation, instances of shared regulatory planning where multiple players are interacting, collaborating, and competing are quite common. This is illustrated in Table 2 by the following different sub-games or gameplay modes: Game A, a "Team-Build," and Game B, a game of "Capture-The-Flag."

Game B involved a more action-orientated mode of game play that required players armed with arrows to engage in medieval combat in a castle setting, attempting to secure the position of the enemies and return it to a home base for points. Points were also awarded for mortally wounding members of the opposing team, causing the deceased to wait a period of time before "respawning" near their own base. Screenshots from these two modes are shown in Table. 2. The differing modes of play impacted upon the team and individual goals, and the rules around interacting with the other teams. Players in Game B could interact in the virtual environment and through text-based chat with their opponents, while in Game A players can only interact with the other teams once the building phase was completed. Focusing specifically on verbalizations or behaviors relating to "planning," there are some interesting contrasts and some surprisingly similarities between the frequency and nature of planning in the two modes of play.

Understanding Regulatory Planning Through Motivation

Grau and Whitebread (2012) describe three sub-categories of planning which may further help in

Shared Regulatory Planning in Minecraft, Table 2 Contrasting two different modes of Minecraft game play

Game A: Team-Build (Gamer Chad 2018)	Game B: Capture-the-Flag (Bajan Canadian 2014)
In this Minecraft game, several teams of players are challenged to construct something around a set theme within a designated time limit and concluding with a vote. The theme this <i>team-build</i> game is about SpongeBob SquarePants, an animated television series created by marine biologist and animator Stephen Hillenburg	In this Minecraft game, two player teams coordinate a competitive game challenge to capture the opposition’s flag on a randomly generated map. It is a variant of a traditional outdoor game where team’s race to <i>capture-the-flag</i> located at the other team’s “base,” then bring it safely back to their own base
	

understanding the implicit motivations underpinning these observed verbalizations and behaviors. One framework that has been used for examining player motivation specifically in online gaming is Filsecker and Kerres’ (2014) Volitional Construct Framework. This framework conceptualizes motivation “as a volitional process” (Filsecker and Kerres 2014, p. 456), which can be understood as a system of psychological control processes that allow individuals to stay focused on achieving a goal and to ignore distractions that are not related to achieving that goal (Filsecker and Kerres 2014; Kuhl 1987). These goals may be a joint team goal in the game, such as winning the Team-Build vote in Game A, or scoring higher than the opposing team in Game B. These goals may also be individual goals, such as building a particular structure in Game A, or one player having a higher individual score compared with the rest of his or her team.

With the use of publically shared artifacts from an online video service, such as YouTube, comes a third meta-goal, attracting more viewers to gain increased revenues. When prioritized by the player, this third meta-goal can result in players acting in a way that seems counterintuitive in achieving the first two goals. It is only when placed in the context of attracting a viewership through providing something “out of the

ordinary” such that running into an enemy base unarmed begins to make sense. This goal-driven understanding of motivation helps us to understand shared regulation when planning the approach to the task, the organization of the players, and the socio-emotional state of individuals within the team.

Examples of Players Being Motivated by Task Planning

The first of these subcodes is *task planning*. This centers around any verbalization or behavior that refers to actions that should be carried out in the future to help achieve the task or team goal. The coding scheme provides number examples of social planning processes being utilized in the context of planning how to approach a task in a primary school Science group activity. These examples provided a series of indicative behaviors or descriptions of what task planning may look like “in action” (Griffin and Care 2014). These are useful in considering what these processes in a games-based context may look like.

Setting the Team Goals

Working towards joint goals requires significant negotiation and planning to manage individual and team objectives. The steps for achieving this and the activation of relevant prior content

knowledge (Grau and Whitebread 2012) is best illustrated using the instances of task planning as outlined in the following two different games in Table 3 below.

When talking about the goals at the start of a game, players will often communicate the goals of the scenario or mode of play. It is a chance to focus a team towards the same mission then ask questions to ensure understanding of the rules or to align personal goals with this team goal. Most of the modes within Minecraft provide a clue as to the goal through the naming of each particular mode. For example, the aim of a game called “Capture-The-Flag” is fairly self-evident. When a team member in Game B reported back that “*Okay I see it, I bring in a flag from that thing,*” they were paraphrasing the goal to confirm their understanding. Whilst the discussions that then followed explored various weapon strengths and access staircases, an important planning alignment had been first undertaken with other team members with the main goal which was established through the design of this mode. This is confirming of the goals for a particular mode of

play is also observed in other modes, such as the Team-Build mode being used in Game A:

*... our theme is SpongeBob ... and we're gonna do (um) like .. where they live and stuff.
... I want to build (um) Patrick's house too.
... Didn't we literally are going to make this Bikini Bottom?*

There is a substantial difference between the nature of the goals being discussed in this example of dialogue and the goal used in the previous example. In the example drawn from Game B, the players are discussing a goal that is established through the design of the mode; it is a goal set by the rules of the game. This second example in Game A discusses a goal that is negotiated by the players; it is a socially constructed objective that fits within the affordances of the Team-Build mode of play. It still draws on the conventions of this mode, as the players are arguing what they will build with the objective of achieving the goal set by the mode of play, winning the end of game vote. This raises an important consideration in analyzing goal setting within multiplayer digital games; game design sets the overarching goals of

Shared Regulatory Planning in Minecraft, Table 3 Examples of instances of task planning observed in Minecraft play

Indicative behaviors from Grau and Whitebread (2012)	Game A: Team-Build (Gamer Chad 2018)	Game B: Capture-the-Flag (Bajan Canadian 2014)
Talks about setting goals	“..our theme is SpongeBob .. and we’re gonna do um like .. where they live and stuff.” “... I want to build (um) Patrick’s house too. (Yeah yeah you) Didn’t we literally are going to make this Bikini Bottom?” (t = 2 m 55 s)	“Okay I see it, I bring in a flag from that thing.” (t = 2 m 24 s)
Formulates a step-by-step strategy before solving a problem	“This is the road Dollastic. Okay, which way do you want it to go? ... Like that way? So right here, you’ll put Sergeant’s house” (t = 33 s)	“Hey guys. Okay, let’s all go down mid. (t = 8 m 53 s) “I’m going, I’m going around. I went around the whole map, I’m sneaking into their base” (t = 9 m 11 s)
Talks about his/her knowledge about strategies or personal resources that can be used in order to solve the task		“So it’s a neutral game so far, I’m at imagine your spawn is just on where they’re running to. It’s great that spawn point” (t = 4 m 45 s) “I get back to the flag faster anyways. That’s actually legit strat, you could suicide and get to the flag quicker” (t = 8 m 30 s) “I’ll be I’ll be a body bag.” (t = 9 m 00 s)

a game, and the boundaries around what is possible, but in many modes of play also encourage a degree of negotiated interpretation by the players.

Pendulous Decision-Making

A player in Game A opened by stating that the team-build game theme was *SpongeBob*. The player then sets out what the other team members will do and gave a clue about the scope of this project, “*where they live and stuff*.” This is quickly followed by a remark by another player that begins to explore a smaller personal goal or house that they want to work towards. This then prompts a further clarification about the central mission “*Bikini Bottom*,” a collection of homes that make up a small city set within *SpongeBob*. The planning at this stage of a game is pendulous, swinging from a main goal to personal goals, then back to a redefined central goal. While aligning players to work towards the same goal is a common planning task, a complication that is novel to many virtual worlds is how to just make them face the same way.

Avatar Alignment and Pointing the Way

The navigation in virtual games is complicated by direction and orientation cues that impact upon planning tasks.

I'm here. I see them there. No look, right here on top of the tower; on top of their tower

For this exchange in Game B, there is a verbal planning direction to make the other characters turn around towards a distant object and face in the same direction. Lacking cardinal directions, this is so that they can align their faces and attention the same way, towards a threat posed by the opposing team, and then agree on the next course of action. Not only is the planning in a virtual world challenged by the lack of clear directions, when a virtual player lacks arms to gesture or a head to turn, then they are even further challenged to point out a particular direction when elaborating upon their plans for a particular task. There are ways of working around this.

which way do you want it to go? . . . Like that way?

For example, a player in Game A attempts to probe the physical direction of a chosen for a

small road construction by building a small section to draw the attention of other team members.

Without physically turning their Minecraft avatar, it is impossible for a virtual player to raise a hand to point in a direction for a particular planning task. They could become conspicuous and make an idea stand out in ways that are similar to we attract attention in the “real world.” A Minecraft player could make their avatar jumping, wave a sword, dig a hole, build a path to show off their actions to make their point clear and their planning task conspicuous.

To guide work on the same planning task in a virtual world with no clear cardinal directions, it is difficult for a player to ensure agreement and progress towards the same goal unless they can make fellow players face in the same direction. By facing the same challenge and problem, then the task planning dialogue can atomize a task into smaller steps that increment towards the same goal direction and the following task. It is at this point that players will exchange questions and trade their ideas.

Sharing Knowledge and Past Experience

One of Grau and Whitebread's most interesting indicative behaviors for task planning is when a person discusses his or her knowledge about strategies or personal resources that can be used in order to solve the task. There were a number of instances of players in Game B sharing strategies that they deemed to be effective. Some of these were more conventional in nature, adhering to time-tested tactics developed and refined in other games with similar modes of play, and then transported to Minecraft's version of Capture-The-Flag.

So it's a neutral game so far, I'm at imagine your spawn is just on where they're running to. It's great that spawn point.

The player shares their personal knowledge of the “great” spawn point, suggesting a level of familiarity with the layout of the map. This is interesting in that while the map is randomly generated, this player has either gained enough experience in the limited play time of this session to make a formative judgement on which “spawn

points” are the most effective, or they have identified a pattern in the algorithm that Minecraft uses to place “spawn points” when generating these maps. This dialogue illustrates how difficult it can be to make distinctions between the four broader processes within shared regulation, as this one sentence shows that the player is both monitoring and evaluating their team members. It draws on the knowledge of the other games of Capture-The-Flag to evaluate the performance of the player’s team relative to their opposition, uses this evaluation to predict the opposition next strategy, and then in the same instance uses this knowledge to inform the suggestion of a potential strategy to counteract the likely maneuverers of the opponent.

As in other virtual and online environments (Hanewald and Gesthuizen 2009), task planning is undertaken by players who seem to be trading a currency of support, thoughts, ideas, and sharing experiences. Perhaps it is not surprising that in virtual games, some players would offer to trade with their life.

Personal Sacrifice and Reputation

In the Capture-The-Flag mode, one player has a rather unique understanding of the mortality of his game avatar as a resource to be exploited in achieving the team goal:

I'll be, I'll be a body bag.

This line suggested that the player was offering to position their character as a physical shield and protect another player running towards the opposing team’s flag. To understand this perspective and planning strategy, it is important to understand that players generally view their virtual character as a respawning avatar and recyclable resource. This strategy offers a chance to boost reputation at the risk at failure. A willingness to sacrifice your individual virtual health to assist the team commands a level of creativity and innovation. It does require that the plan is accepted by the other team members.

Justifying Your Plans and Planning by Nudging

Players in a virtual world can easily be seen as being distracted or working off-task. To counter

this, they may need to articulate a modified plan that will justify their action or move that they are planning. Two examples of this occurred during Team-Build Game A when it briefly appeared that a player was briefly off-task as they were building a floor in their building and when they had found a fun feature such as a bubbles action that was worthy of distraction.

I need to make sure we get this or the ground in there would be a hot mess, okay?”

“Oh Lets see, I’m gonna go hide it back here, just in case it’s bad

When planning, players will give repeated verbal instructions to nudge another player into the correct position or a construct in a particular direction. While emphasis can be given to a planning task instruction by speaking louder or inflecting the voice, without the benefit of a visual expression or gesture, players can still give due emphasis towards their instructions by repeating them or gently prod another player into a desired location or build position.

.. a bit taller. I'll be telling just a bit though, just a little bit, just a little bit.”

“.. Please step down, one more step down

Unlike working in the real world of a classroom, laboring on a complex task in a virtual world requires more explicit instructions to help change the behavior of other players. This can wildly vary from a gentle push to move a single block to a boldly unorthodox maneuver that threatens to undermine the unity of a team or destroy the spirit of the game.

Planning Your Task Legitimacy and Morality

Game B Capture-The-Flag involved an interesting discussion about the morality, “legit” or legality of a particular game action or nuances that would advantage them. One player in this game used a particularly unusual movement across the game map by sacrificing themselves but felt it necessary to firmly articulate the details of what they were planning to other team members.

I get back to the flag faster anyways.

That's actually legit strat, you could suicide and get to the flag quicker . . .

Okay, just keep coming down.

Okay, watch out this is legit. This is like, this is serious business guys

The exact location of random spawn point where a team player reappears after their demise could provide that team a slight advantage by the novel strategy of a highly unusual but unexpected movement across the game map. Anticipating the potential for scorn from fellow team members, this player has emphasized the legitimacy of the movement, reinforcing that the advantageous movement was not restricted by any explicit game rules. In a sense, this player is using their task planning to affirm the legitimacy of the action that they are seeking and permit its adoption and use.

*Okay, I'm sneaking around seeking staircases.
I'm sneakin, I'm sneakin.
Okay I've got the flag*

For example in this dialogue from Game B, a player is similarly detailing their planned movements across a map. Many first-person shooting gamers express a disdain for players that hide their position on a map, avoid any obvious movement, then “snipe” or shoot from a distance, a behavior that is derogatively described as “camping” (Ash2x 2007). It seems to be considered more dignified to give the other team a fighting chance by encouraging moving about while you are shooting with the added skill of avoiding becoming a target. By contrast, it is considered fair game to move about the map in secret. What is interesting with this line of dialogue is that the player is attempting to explain their covert actions to verbally justify the morality of their chosen online behavior to the other team players. They are clearly engaging in a form of social regulation.

Examples of Players Motivated by Organizational Planning

The second subcategory of planning is referred to as organizational planning which involves the participants planning the organization of the task at a pragmatic level, such as allocating roles and setting expectations of individual contribution to the team. Instances of organizational planning were observed in both Game A and Game B, although these manifested in different ways. Once again, the rules of play dictated by the game design interwoven with the social norms of each respective sub-community resulted in contrasting expressions of this process, as outlined in Table 4.

Egocentric

Many statements shared in virtual environments are egocentric in the sense that they notified teammates about what a player was intending to do. Reviewing the instances of organizational planning observed in Minecraft listed in Table 4, a number of considerations become apparent from the dialogue shared in Game A.

*I think, I think I'm gonna try to do like the Krista the Krusty Krab.
I don't know if I have time I believe, but I'm gonna try*

This can be interpreted in a number of ways depending on the allocation of social capital within the group. It may be the case that this player feels inferior to their teammate, sensing that they don't have an equal level of experience and hence are in no position to dictate what their peer should be doing with their limited time. Alternatively, they may see their peer as being inept and

Shared Regulatory Planning in Minecraft, Table 4 Instances of organizational planning observed in Minecraft play

Indicative behaviors from Grau and Whitebread (2012)	Game A: Team-Build (Gamer Chad 2018)	Game B: Capture-the-Flag (Bajan Canadian 2014)
Student plans the organization of the task in a pragmatic level (who is going to do what)	“I’m gonna go and get stuff for SpongeBob’s little house.” (t = 59 s) “I think, I think I’m gonna try to do like the Krista the Krusty Krab. I don’t know if I have time I believe, but I’m gonna try” (t = 4 m 45 s)	“I’ll be the defenseman, I’m gonna post up, I’m gonna post up.” (t = 1 m 32 s) “You want to run the flag?” (t = 3 m 03 s) “I got three and got one of them at almost. Tyler, I’m just distracting. Mitch I’m just buying you time” (t = 5 m 57 s) “Yeah okay I’m through them, through big. I’m going the left side, protect my left side.” (t = 10 m 16 s)

feel that they will have to engage in most of the construction as a unilateral act if their team is going to be competitive in the Team-Build game. It is important to note that unilateral planning and action is not necessarily selfish in nature, as they can be an important process in having a team adjust an unsuccessful strategy.

Sense of Task Urgency

The examples elicited from Game B also show how the sense of urgency provoked through real-time interactions with an opposing team require more spontaneous and shorter-term planning, with less dialogue dedicated to planning for the “long game.” Instead, players were largely observed planning their response to events that had just occurred. Considerable dialogue involved adjusting their strategies in response to a defensive breakdown around protecting their flag.

I'll be the defenseman, I'm gonna post up, I'm gonna post up.

This dialogue from Game B follows the team ceding their flag to the opposition. There is a sense of urgency to this comment, with the player fearing that the opponent was nearby, and that another successful maneuver by the opposition could shift the momentum irreparably in the other team's favor. Through conveying these fears to the rest of team, the player signals a perceived need for a change in team strategy. Recognizing and communicating this recognition for adjustment is an important process within organization planning. It gives notice about continued engagement and the scope for plans to change.

Changing Task Strategy

This is a recognition that a change in strategy is required, with the need for a more defensive posture. Within the broader cycle of shared regulation, this verbalization can be seen as serving dual purposes. It is both a pragmatic allocation of human resources and perhaps more contentiously a subtle reminder to the other players of the need to play a defensive role, as opposed to prioritizing individual glory and focusing on the thrill of capturing the opponents flag. This shift in emphasis from prioritizing exhibitions of individual skill

towards planning coordinated strategies where players are willing to take on a secondary role was also seen in the team's offensive endeavors. Through subsequent cycles of attack on the enemy base, it can be heard by one player that someone else should be going for the flag while the player will protect the designated flag carrier:

You want to run the flag?

Adjusting the plans at the shared-level requires some degree of recognition from the other players that the existing plan is unlikely to succeed. The degree to which players change their actions as a result may reflect their confidence in this plan but can also be influenced by their own self interests. They are foreseeably much less likely to agree to a plan if they perceive this new course of action as disadvantaging their process towards their individual goals, such as gaining the most enemy “kills.” This is tension between individual success and group success is a recurring theme when considering organizational planning.

Unilateral Organization Within the Team

In the duress of a competitive game, players are often forced to make decisions without consulting their peers out of necessity. In Game B, for example, players in the game explained a strategy that involved a measure of self-sacrifice for the greater good of a team. In one instance, one described themselves as becoming a “body bag,” hinting at a strategy that would involve their easy death by the opposing side. Another player verbally justified their planned reckless behavior to reassure the other team members:

Tyler, I'm just distracting. Mitch I'm just buying you time

This dialogue between two attacking players shows an instance where one player has unilaterally recognized that effective planning requires more time and has decided to take matters into his own hands. Although the planning has occurred at an individual level, the player needs to share his plan with his peers to put it into action. As the first player has already begun to put this plan into action by jumping around and drawing attention from the opposition, the other players

need to evaluate the effectiveness of this plan and then either accept it or form an alternative plan. Shared planning requires a complex consideration for both individual and group goals, although as the above example shows, the social goals are ultimately filtered by interpretations of the “team goal” by individual players. Although planning at a shared-level allows for the declaration and careful consideration of every player’s individual goals, the added pressure of a time limit in Game A and an opposing team in Game B can disrupt these negotiations. This can leave players making unilateral decisions that they believe are in the best interests of the team.

Planning Roles Within the Team

As Game B progressed, the pendulum between planning pragmatic roles gear towards either individual success or team success swung back towards prioritizing the individual player. This was likely a conscience of victory for the player’s team at this late stage of the match being seemingly assured:

Yeah okay I'm through them, through big. I'm going the left side, protect my left side.

In this dialogue, the player is still planning the roles of the other players but sought to coordinate them in a manner that positioned himself as the central protagonist in the action. This position of the self as the hero through this pragmatic organization reflects both the power dynamics within the group and brings to mind questions player perception of individual identity within the group. This player wanted to be perceived by his peers as the hero, seeking to align perceptions of his individual success with the team achieving their common goal. This careful framing of socio-

emotional planning dialogue can help mitigate unwanted responses by other team members and their steer perception of the player as focused on the welfare of the team.

Examples of Players Being Motivated by Socio-emotional Planning

Finally, Grau and Whitebread suggest a third subcategory of planning entitled “socio-emotional planning.” This involves preempting what other people may feel and planning a way to avoid negative or unwanted emotional responses from peers. This is the most interesting category, as there are no examples provided by Grau and Whitebread (2012) in studying collaborative interactions in the primary Science classroom. This is where examining social regulation through the context of the lens of Minecraft becomes particularly interesting. Three instances that could be classified as socio-emotional planning were found in both Game A and Game B, as highlighted in Table 5.

Unraveling the planning process in any online game requires a measure of subjective interpretation grounded in a clear understanding about the culture within and surrounding the game. To draw a connection between planning for the emotional state of the other players and the associated dialogue requires an understanding of the social norms found within Minecraft communities and an understanding of the design of the respective modes of play. In the Game B Team-Build example, a planning instance can be classified as socio-emotional planning when one player prefaces her critique of her peer’s taste in architecture with the phrase “OK, I mean it looks really good,” preempting his foreseeable displeasure about

Shared Regulatory Planning in Minecraft, Table 5 Instances of socio-emotional planning observed in Minecraft play

Indicative behaviors from Grau and Whitebread (2012)	Game A: Team-Build (Gamer Chad 2018)	Game B: Capture-the-Flag (Bajan Canadian 2014)
None provided as Grau and Whitebread reported they did not observe any instances of socio-emotional planning	“OK, I mean it looks really good but I don’t like it. It should be 3D.” (ref here)	“You ever ate butter with a spoon, <i>that’s how it’s gonna be.</i> ” (t = 1 m 41 s) “Listen they needed that, they needed that. You don’t mean cuz they were getting really demoralized, so this is good alright” (t = 1 m 22 s)

receiving negative feedback on his plans for a particular component of SpongeBob's house. By including this phrase, she is acknowledging the emotional connection he may have developed to his work. In an arguably unrefined manner, she is trying to both praise his effort and share a critique about the product of his labors.

Maintaining a Balanced Team Mental State

Reviewing the instances of socio-emotional planning in the game of Capture-The-Flag also requires a deeper understanding of this mode of play. This mode is more intensively competitive by design, with a game being scored in real-time through a combination of enemy "kills" and flag "captures." A player and a team's relative success is broadcast to everyone playing or observing the match, with the game providing instantaneous feedback on an individual's performance for the world to see. This public sharing of an individual's contribution to the success, or lack of success, in achieving the team goal may foreseeably have a toll on their performance. Just as talk about baseball players who "get into a rut" and are seemingly unable to hit the ball, competitive gamers can falter under the glare of a public audience (Jin 2010). This can occur despite their objectively high level of playing experience and past successes. Following this logic, the other players have a vested interest in maintaining an individual player's emotional state in this more competitive environment. In Game B, this planning for a "winning" team mindset begins early, with one player predicting that:

You ever ate butter with a spoon, that's how it's gonna be.

This seemingly boastful comment, comparing the perceived "easy" level of competition from the opposing team to a hot spoon easily digging through butter can be interpreted in a number of ways. One interpretation is that the comment was designed to be reassuring, allaying the fears of his teammates and reducing the levels of anxiety about playing on an unknown, randomly generated map. This preempting of a negative emotional state is also evident when considering later dialogue after a significant individual error, which

could have had ramifications for achieving the collective goal:

Listen they needed that, they needed that. You don't mean cuz they were getting really demoralized, so this is good alright

These are the affirming words from one player to his teammate after he failed in his designated role of defending his team's flag. The player was caught unaware and was killed by an enemy player, leaving their flag vulnerable. From this event, the opposing team scored a much needed victory. The affirming player has identified that this player is most likely feeling responsible for this loss and has reminded him and the rest of his team that they still maintain a significant score advantage over the other team. All three examples are interpretations of dialogue through the lens of socio-emotional planning, with other equally valid interpretations of the dialogue being possible. What they serve to do is provoke thought about the value that players place on the emotional state of their peers, and of this may be strategically manipulated through bilateral and whole team communication.

Conclusions: Social Regulation Within Multiplayer Digital Gaming

Educational systems in developed economies are increasingly called to assist in the transition from a manufacturing-based economy to a knowledge-based economy with a priority placed on "soft skills" (Lay and Kamisah 2017) such as the set of effective collaboration skills privileged by both educational theorists and economists (Griffin McGaw and Care 2012). Central to these skills are the processes of social regulation. Grau and Whitebread's coding scheme can help identifying and classifying "real world" observations of the processes and subprocesses within regulatory planning. As a tool, it can help understand the potential motivations underpinning these processes. The provision of a common vocabulary, alongside the indicative behaviors, allows for a comparison between the frequency and nature of regulatory planning in physical spaces. This is the

basis for an improved model that better describes and defines the ways that social regulatory process can occur within simulations and virtual environments such as the Minecraft game. The model will need to consider the complex relationship between the virtual environment design, artifacts, location, and social regulation.

Pertinent questions include:

1. What are the differences between players engaging in online play and local multiplayer, and where players are co-located in a shared physical space?
2. What is the role of game design in promoting social regulation?
3. What is the relationship between people using these processes in a designed virtual environment and people using them in other contexts in the physical world?

Whether it is working together to build SpongeBob's house, designing a sustainable form of transport, or undertaking a joint experiment in a Science class, when people are working and planning together on a shared task, a refined understanding of these social regulatory processes will assist with their effective collaboration.

A dedicated coding scheme that derives from this model would allow for a nuanced study of the social regulation of cognition, emotion, and behavior in a virtual context. Not only would this be an asset in developing better games by incorporating principles that encourage positive social regulatory processes, an improved understanding of the relationship between virtual world design and its influence upon player interaction could have wider implications for the design of these virtual environments and other simulations.

Cross-References

- [Game-Based Learning](#)
- [Games, Simulations, Immersive Environments, and Emerging Technologies](#)

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Simulation Games

- [Games in Higher Education](#)

Simulation Games, and Serious Games

- [Digital Simulations in Healthcare Education](#)

Situative Perspective

- [Situative Perspective and Determinants of Technology Acceptance in Educational Technology](#)

Situative Perspective and Determinants of Technology Acceptance in Educational Technology

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Synonyms

[Situative perspective](#); [Technology acceptance](#); [User motivations](#)

Technology acceptance studies in education have proliferated in recent years. As education technologies take on more prominent roles in education, it has become necessary to study the antecedent factors to students' acceptance of technology to ensure the adoption of innovative and proven education technologies. Technology acceptance is based on the observation that user motives affect acceptance of technology (Davis 1989). The field of technology acceptance aims to identify the motivational factors determining intentions and use of technology.

The technology acceptance literature is grounded in the cognitivist perspective, taking inspiration from the theory of planned behavior and the theory of reasoned action. Technology acceptance researchers have also been informed by innovation diffusion theory, social cognitive theory, and self-determination theory, among others, as they have sought to understand the

determinants of technology acceptance. Subsequent to Davis' (1989) original formulation of the Technology Acceptance Model (TAM), many extensions have been proposed, reflecting the wide ranging contexts of technology applications. More recently, attempts have been proposed to create a unified theory of technology acceptance and use (Venkatesh et al. 2003). While some have pointed to the proliferation of models as a shortcoming of technology acceptance models, others have argued that the parsimonious character of the core factors of the TAM is a strength, because it recognizes the contextual specificity of technology application situations (King and He 2006; Sun and Zhang 2006; Venkatesh et al. 2003).

The TAM is composed of five key constructs: Perceived Usefulness, Perceived Ease of Use, Attitude, Behavioral Intention, and Use. According to the TAM, the actual use of a technology is determined by the user's behavioral intention to use the technology. The user's behavioral intention is an immediate antecedent to use of the technology; whereas, the user's attitude toward the technology determines their behavioral intentions. Perceived usefulness and perceived ease of use are two fundamental antecedents posited to influence attitudes toward use. The original TAM advanced that perceived ease of use influences perceived usefulness, and perceived usefulness is also related to behavioral intentions. The TAM has garnered substantial empirical support and is one of the most widely employed models. All the core relationships, save the more questionable link from perceived ease of use to perceived usefulness, have been replicated across a wide range of contexts.

Whereas technology acceptance investigations around exogenous antecedent variables have been focused on user beliefs (Bagozzi 2007), attempts have been made to incorporate situational factors to account for the contextual specificity of technology applications as TAM has historically explained less than 50% of variance in user behavioral intentions (Venkatesh et al. 2003). To the extent that situational factors are

considered, they have been often relegated to single factors such as Subjective Norm, Voluntariness, or Facilitating Conditions (Venkatesh et al. 2003). However, the situative perspective (Greeno 2011) militates more broadly for the influence of situation on user's beliefs. In this perspective, a user's beliefs are reflexively determined through their participation in the situated activity and meanings (Gee and Green 1998), and conversely, situated meanings and activities are constituted in users' perceptions of the situation. In practice, meanings, including beliefs, are inseparable from the contexts of use. Concretely, what this suggests is that choices of technology are constrained by the situations and activities that employ the given technological tool to accomplish specific objectives. Thus, participants' choices do not operate independently and technology acceptance cannot simply be conceived as a function of user beliefs. A useful example is provided by social media technologies since the technology represents a platform for community, the affordances of the technology are reflexively determined in the dynamic interactions between individuals and collectivities. In other words, Twitter, Facebook, and Instagram offer greater affordances than any other functional replicas from a horde of copycat social media applications that offer neither the scale nor the depth and range of human contact and ingenuity provided by high levels of social adoption of the preeminent platforms. However, as the founders of these preeminent platforms recognize, the platforms depend crucially on their communities. Indeed, their value lies in the communities they have built. This inescapable duality is central to the situative perspective. In other words, technology acceptance must be conceived within the frame of activity that the technology in question enables or facilitates – its conditional affordances (e.g., usefulness, ease of use) – but where such technology is integral to the activity, such as the social media platform, we must also consider that the activity itself limits the range of acceptable choices, whether on a socio-organizational, technological, or

individual level. You may choose any social media technology from an ever-growing list of options; however, the community or activity that you wish to engage with will dictate the technology that you are required to accept. Such considerations move us beyond the scope of voluntariness, social norm, or facilitating conditions – all which have been conventionally defined with regard to individual cognitions. Increasingly, social media technologies are required for participating in many professional communities or communicating with the marketplace. In these situations, user beliefs such as perceived usefulness and perceived ease of use only provide a partial explanation of individual technology acceptance as determinants of user actions in social contexts are often grounded in social imperatives. To the extent that social participation in a community is contingent on acceptance of some technology, a user will find their choice constrained by necessity.

The situative perspective on technology acceptance holds that situational determinants operate on the whole model, that is, on the core factors and path relationships as well. In other words, according to the context of technology use, certain factors may take on more or less salience. For instance, the workplace has been shown to influence users' behavioral intentions, as employees may have little or no choice in the technology they use (Sun and Zhang 2006; Venkatesh et al. 2003). The influence of the organizational context on user's beliefs is suggestive of a class of moderating influences on technology acceptance that has not received due consideration. Whereas TAM is grounded in user beliefs, little attention has been given to the influence of the modality of these beliefs on the core TAM constructs. However, such modalities appear to interact with situational determinants to influence contexts of technology acceptance. Doleck et al. (2017a) proposed an organizational matrix, adapted from Sun and Zhang's (2006) synthesis of the literature on moderating factors on the TAM, that illustrates how moderating influences on the TAM can be conceived as resulting from the interaction of

situational and modal characteristics. Moderating influences such as voluntariness, individual/group dynamics (i.e., subjective norm), and cultural background are conceived in terms of the modality of necessity, such that a user may feel internally compelled or externally constrained to use a certain technology. Other moderating factors that may determine use as a requirement of the task, activity, or profession may be conceived in terms of the modality of certainty. For instance, where performance stability, safety, trust, or uniformity in application is a requirement of the activity (e.g., failsafe), legacy systems may be preferred even though better options may be available. Finally, technology acceptance beliefs may be classified as a function of the modality of possibility or conditionality (e.g., affordances) where the technology application is oriented to solving complex problems or fostering innovation. Such innovative uses may be witnessed in the rapid and unceasing proliferation of web programming frameworks, all proposing novel solutions and providing new extensibility to the original problem of delivering web content.

Research demonstrates that external factors exert a strong influence on core TAM constructs and are often as important if not more important sources of explained variance on both behavioral intentions towards and actual use of technology. In a series of studies exploring technology acceptance among students and general population (Doleck et al. 2017a, b; Lemay et al. 2017), factors expressing the modality of necessity were shown to strongly influence attitudes, behavioral intentions, and use of social networking, imaging sharing platforms, and online and computer-based education. In these contexts, the perceived necessity of the technology contributed large amounts of variance explained over the contribution of the conditional affordances of perceived usefulness and perceived ease of use. Thus, considering the modality of the underlying beliefs informing technology acceptance helps researchers situate technology within the frame of social activity. By helping to better conceptualize the range of constraints and affordances of

technology, the language of modality helps understand the situational determinants of technology acceptance and use.

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Smart Board Technology in Higher Education Institutions

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Introduction

There are many forms of Interactive White Board Technologies (IWBT), but usually an IWBT combines an electronic touchable whiteboard connected to a network computer and a data projector. IWBT allows teachers and students control applications by touching the screen with their fingers or writing digitally with a non-ink pen tool. The touch-sensitive nature of IWBT facilitates more efficient presentation and more professional delivery of multimedia resources (Smith et al. 2005).

The IWBT or the smart board is believed to increase the effectiveness of teaching both qualitatively and quantitatively and to greatly facilitate the use and benefits of computers and the Internet for teachers (Somyürek et al. 2009). IWBT represents a tool and an environment that promotes dialogue and knowledge building among students (Warwick et al. 2010). Students can benefit from the different learning styles provided by IWBT features and software application where students could see, touch, and hear the content of the lesson. Therefore, IWBT promises to elevate teaching to new heights and represents a key enabler for the creation of student-centered

Skills

► Teaching with Computing, Educational Games

collaborative environments (Somyürek et al. 2009) and hence could foster performance parity and increase student achievement (López 2009). Similarly, IWBT is considered an effective interactive learning approach and is being used in teaching and grading and expected to alter current pedagogical system and means of exchanging information with students (Stoica et al. 2011). For teachers, the IWBT made their lessons more enjoyable, and for students, the IWBT resembled an opportunity to actively participate in a lesson and to internalize inputs in a more appropriate manner (Gursul and Tozmaz 2010).

However, upon a thorough consideration of IWBT literature, it was observed that many challenges surround the successful adoption and usage of this technology. Slay et al. (2008) found the IWBT research divided into two areas: investigate the use of IWBT in particular subject areas and solicit teachers' and learners' perspectives on the IWBT technology. At the outset, although integrating technology into teaching and learning is growing, non-anecdotal evidence of IWBT effectiveness in teaching and how to implement a successful IWBT classroom is lacking (López 2009) and even controversial (Gursul and Tozmaz 2010). For example, Warwick et al. (2010) found existing IWBT research focusing mainly on teacher–pupil interaction and ignored pupils' collaborative needs. On the other hand, other researchers noted that existing IWBT research focused on the effective use of IWBT in the classroom and its impact on student's academic achievement and largely ignored teachers' opinions about IWBT (Gursul and Tozmaz 2010). This scant research (Somyürek et al. 2009) reported limited successes with IWBT and failed to clearly state the problems and solutions and the successful implementation of IWBT in teaching (López 2009).

In looking at some adopted approaches, Warwick et al. (2010) noted that the introduction of new technologies in teaching did not address its link to pedagogy as such. This is aggravated by the attempt to introduce new innovations like the IWBT into old educational models (Warwick et al. 2010). Korucu et al. (2011) even questioned

whether teachers are capable of using IWBT or not.

Therefore, it is not surprising that researchers like Lopez (2009) asserted that innovative technologies like the IWBT must be introduced as a disruptive innovation, where it should not compete with existing current curriculum and instructional practices but rather to challenge the teachers' ability to discover new features in IWBT and use them to devise new ways of teaching. Accordingly, educators should develop accurate plans and strategies to integrate technology into teaching as educators may lack a clear understanding of the pedagogical principles underlying integrating these new technologies in the classroom (Salinas 2006; Somyürek et al. 2009). For example, Stoica et al. (2011) highlighted the importance of addressing student's cognitive capacity and limit and that teachers must always be alert about their objectives and in identifying appropriate content and assessment techniques. They indicated that students working in teams are more inspired and more excited where, for example, with the aid of the IWBT, collaborative students could intricate their conceptual micro-maps more effectively.

Interactive White Board

Korucu et al. (2011) shed more light into teacher's perceptions toward IWBT usage and reported that teachers agreed on the positive impact of interactive materials in the classroom despite its scarcity and limited use in the classroom. Teachers reported difficulty in using IWBT and interactive materials (including visual and animation content) and in creating it. The same researchers found that although most teachers raised the importance of having IWBT in all classrooms, they did not prefer using interactive material and viewed IWBT as not to have a positive effect on the courses they teach.

This confusion in IWBT research and in appraising the outcomes of IWBT could be attributed to the lack of knowledge about the effective use of IWBT in the classroom. Teachers with

limited knowledge in technology would refrain from using the IWBT because portable IWBT requires adjusting its calibration settings, more frequently (Gursul and Tozmaz 2010). In the same vein, Korucu et al. (2011) contended that it is essential to strike a match between teachers and IWBT capabilities for IWBT to succeed in education which could be bridged by in-service training. Gursul and Tozmaz (2010) contended that once IWBT is integrated correctly into the curriculum and this process is continuously employed, the IWBT could prove to be a revolutionary invention for schools. To elevate the argument further, Warwick et al. (2010) concluded that technology alone cannot change classroom teaching and learning but rather requires mediation by the teacher. Hence, the teacher role is not confined to direct intervention which will scatter pupil interaction at the IWB but to developing innovative ways which employ his/her pedagogical knowledge to come up with appropriate learning tasks.

Student's use of IWBT is also limited. For example, Gursul and Tozmaz (2010) found that the activities carried out by students on IWBTs were limited to using it for normal board activities (solving questions, writing, etc.) (29%), and explaining things which would otherwise be impossible to do so in classrooms through animation (23%). They reported scant use of the IWBT in carrying out interactive activities such as matching, dragging, and painting; permission to control the computer; and making children play games related to the subject of a lesson.

IWBT provides many benefits to teaching, such as offering flexibility, versatility, multimedia ability, efficiency, interactivity, lesson participation, collaboration, idea sharing, motivation, instant access to vast electronic resources, and the ability to save and post drawings and writings on the board (Slay et al. 2008; Smith et al. 2005). Lopez (2009) found that digital learning classroom promotes positive social norms and a learner-centered pedagogy where both teacher and students are learners, which allows for the development of common themes and shared meanings. Teachers began sharing their direct instruction with the IWBT and students

interacted with the IWBT when they were prompted by the lesson unit. Smith et al. (2005) highlighted that teacher-student interactivity is the primary benefit of the IWBT. Slay et al. (2008) reported the following advantages from a teacher's perspective:

- a. Seamlessly access one resource after another from the board
- b. Allow teachers to support multiple needs within one lesson
- c. To draw from countless multimedia sources
- d. Ability to face the class while teaching which allows teachers to maintain class control
- e. To be more in touch with the learners by maintaining eye contact than when using a laptop and from a learner's perspective:
- f. Saw IWBT as effective tools for initiating and facilitating the learning process, in particular when they were given the opportunity to use the IWBT themselves
- g. The visual nature of the IWBT allows for different ways to presented information which reinforce concentration and attention
- h. Learners pointed to their teacher's lack of ICT skills, associated cost of IWBT technologies, and the technical reliability of the IWBT as disadvantages of the technology

Slay et al. (2008) highlighted six factors that were consistently reported by the literature to influence teachers' and learners' use of the IWBT and reported the following theoretical implications:

- a. Improved visibility of classroom content
- b. Value of multimedia content (audio/videos, online/offline content, etc.)
- c. Motivational use of up-to-date technology where the contradictions here are twofold
- d. Interactive affordances
- e. Lack of ICT literacy and competency
- f. Cost

In the same vein, Somyürek et al. (2009) found teachers, though not having a negative attitude toward ICT, reporting the following reasons for the limited use of IWBT:

- a. Lack of technical competency on how to use IWBT
- b. Lack of pedagogical competency on how to integrate them into classroom activities
- c. Lack of a school plan on the use of IWBTs
- d. Lack of both technical and pedagogical in-service trainings and how to integrate IWBT into the learning processes
- e. Lack (number and quality) of digital educational materials to highlight the advantages of multimedia, including static and dynamic images, sounds, videos, animations, web sites, presentations, and text editors
- f. Lack of support and maintenance
- g. Administrative concerns: lack of measures to monitor the use of IWBT and the failure of school administrations to encourage teachers use the IWBTs, scheduling of ICT installed classrooms, and sharing of digital educational materials among the teachers

Schmid (2008) addressed the notion of effective multimedia integration in IWBT-based classroom and reported the following:

- a. Advantages: Use of multimedia in IWBT-based classroom facilitates students' learning processes
- b. Challenges: teachers and learners faced in the process of multimedia integration

Table 1 shows a thorough examination of these factors alongside four main themes: advantages, complexities, management support, and compatibilities. This table also shows the questionnaire development criteria which is explained next.

Case Study

UAE University (UAEU) is the first national (federal) university in UAE. It was established in 1976. The university's founding mission was to realize the aspirations of the society, deepen social ambitions, and consolidate the structural foundations. As of 2011, the UAEU has over 12,000 students, primarily based in Al Ain city. UAEU has over 650 teaching-faculty members and offers

bachelor degrees, postgraduate courses, PhD programs, and continuing education programs for the community at large.

Data for the study was collected in 2011 by means of a survey questionnaire based on the research model in Table 1. Standard measures were used (where available) during the design of the measures adopted in this study. Some of the previously validated measures had to be adapted to meet the constraints of this questionnaire. Table 1 shows the development of the different research variables in the research model and their measures. On a scale of five-point Likert scale (1 = Strongly disagree, 5 = Strongly agree), respondents were asked to provide their opinion about the different characteristics of the IWBT in relation to teaching in the classroom.

Before the questionnaire was emailed out, it went through extensive pretesting with teaching-faculty members. Particular attention was given to wording, structure, sequence, and overall presentation of the items in the questionnaire. The questionnaire was pilot-tested with 15 teachers. Interviews were conducted with those teachers to determine whether there was any problem with the questionnaire questions or format. On the basis of their comments, changes were made to the questionnaire to clarify wordings and increase readability. Four teaching-faculty members further revised the final version. The pre-testing procedure is important to establish content validity. Responses from the piloted teachers were not included in the survey.

An online version of the survey was created and posted on the university's web site targeting all teaching-faculty and instructors. Two hundred and twenty-eight responses were received. The effective response rate was 35.1%. The questionnaires were coded and keyed into the SPSS statistical software tool. The following tables show statistical details about the sample and IWBT.

When asked whether teaching-faculty adopt or not adopt IWBT, 93% were found adopters and 7% did not adopt IWBT (Table 2). Usage as a measure provided more accurate depiction of IWBT penetration in UAEU. As can be seen from Table 2, the majority of surveyed teaching-

Smart Board Technology in Higher Education Institutions, Table 1 Theoretical IWBT adoption framework

#	Item	Source
	Advantages	Adapted/extended
	IWBT better relieves physical fatigue IWBT enhances the preparation and the management of my class IWBT offers better features	Baek et al. (2008)
	IWBT offers more visualized content (graphics, colors, web sites, etc.) (Schmid 2008; Slay et al. 2008; Smith et al. 2005) IWBT provides better exercises and assessments IWBT provides more variety of teaching methods (Slay et al. 2008; Smith et al. 2005) IWBT provides easy access to different resources at the same time in the classroom (newly introduced) IWBT allows the instructor to satisfy multiple learning needs within the one lesson (newly introduced) Using the IWBT in the classroom increases instructor-to-student interactions (Slay et al. 2008) Using the IWBT in the classroom increases student-to-student interactions Using the IWBT's different resources enhances the student's conceptual understanding Using the IWBT's different resources in the classroom enhances the student's practical understanding (newly introduced)	Barak (2007)
	IWBT offers more flexibility IWBT provides better lesson participation from students IWBT provides better collaboration between students (also adapted from Schmid 2008) IWBT enhances idea sharing in the classroom Ability to save and post drawings and writings on the board I save notes made on the IWBT for later use by me or students I post (e.g., email) saved notes made on the IWBT to students	Slay et al. (2008), Smith et al. (2005)
	IWBT in the classroom promotes positive social norms and habits IWBT promotes learner-centered teaching	Lopez (2009)
	IWBT enhances the facilitation of learning IWBT in the classroom saves the instructor's time Compared with earlier practices and technologies, the IWBT gives me more time to face the class (also from Slay et al. 2008)	Schmid (2008)
	Complexity	
	IWBT fails more frequently during the class session (also from Slay et al. 2008) IWBT faces more hardware problems in the classroom (also from Somyürek et al. 2009) IWBT faces more software problems in the classroom (also from Somyürek et al. 2009) IWBT takes longer time to repair (newly introduced) IWBT requires more specialized technical expertise to fix it (newly introduced) Learning about the different information technology resources for me in the classroom is difficult for me (newly introduced)	Baek et al. (2008)
	Lack of technical competency on how to use IWBT Using the IWBT in the classroom is easier for me (newly introduced) Integrating course-content with the IWBT is an easy task for me Lack of digital educational materials to highlight the advantages of using the IWBT in the classroom Lack of support and maintenance limits my ability of using of the IWBT in the classroom Virus problems cause the IWBT to run inefficiently	Somyürek et al. (2009)

(continued)

Smart Board Technology in Higher Education Institutions, Table 1 (continued)

#	Item	Source
	Management support	
	The university/teaching-faculty have a clear plan for the effective use of the IWBT in the classroom The university/teaching-faculty provide sufficient technical training on how to integrate the IWBT technology into the teaching processes The university/teaching-faculty provide sufficient teaching trainings on how to use the IWBT for teaching The management puts measures and procedures for the effective use of the IWBT in the classroom The management supports the effective use of the IWBT in the classroom (newly introduced) The management is involved in the effective use of the IWBT in the classroom (newly introduced) The management leads the effective use of the IWBT in the classroom (newly introduced)	Somyürek et al. (2009)
	Compatibility	
	IWBT features are suitable to the course content that I teach in the classroom (newly introduced)	
	Have enough time to use the different features of the IWBT in the classroom (also from Barak 2007) Have enough time to fix problems with the IWBT during the class session (also from Barak 2007) Have enough time to call a technician to fix a problem with the IWBT during the class session (also from Barak 2007) The IWBT fits with the way I like to teach in the classroom (newly introduced) I am just using the basic functions of the IWBT in the classroom Using the IWBT in the classroom could result in losing personal contacts with students (also from Barak 2007) I feel that I must use the IWBT in my teaching Using the IWBT in the classroom attracts positive attention to me	Baek et al. (2008)
	I am motivated to use the IWBT in the classroom Using the IWBT in the classroom motivates my students to learn (newly introduced) The IWBT allows me to face the class while teaching which allows me to maintain class control The IWBT allows me to be more in touch with students by maintaining eye contact	Slay et al. (2008)
	I am comfortable dealing with the different multimedia resources accessed by the IWBT Using the IWBT in the classroom limits the student's ability to practice other learning activities during the class I feel that using the IWBT in the classroom limits the exercise of other teaching methods and styles	Schmid (2008)
	I am comfortable with the way the IWBT equipment is installed inside the classroom	Somyürek et al. (2009)

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Smart Board Technology in Higher Education Institutions, Table 2 Adoption versus usage

Adopt IWBT	Freq.	%	Using IWBT	Freq.	%
Yes	212	93.0	I do not use the IWBT	16	7.0
No	16	7.0	I use the IWBT occasionally or sometimes	48	21.1
			Using the IWBT frequently	164	71.9
Total	228	100.0	Total	228	100.0

Smart Board Technology in Higher Education Institutions, Table 3 Demographics data about teaching-faculty

Education level (highest degree)	Freq.	%	Original nationality	Freq.	%	Own laptop	Freq.	%	Gender	Freq.	%
Diploma	1	0.4	Emirati	29	12.7	Yes	224	98.2	Male	183	80.3
Bachelors	4	1.8	Other Arabs	130	57.0	No	4	1.8	Female	45	19.7
Master's	29	12.7	Westerner	56	24.6						
PhD	194	85.1	Other nationalities (Indian, Pakistani, etc.)	13	5.7						
Total	228	100.0	Total	228	100.0	Total	228	100.0	Total	228	100.0

faculty were frequent users of IWBT. This is an indication of the large-scale diffusion of the IWBT in the UAEU as there is no other alternative to the IWBT in the classrooms. Interestingly, 7% of the teaching-faculty did not use the IWBT and 21% reported using the IWBT occasionally. This finding could be attributed to the fact that not all the classrooms were furnished with IWBT or such teaching-faculty did not use any illustration tool or saw limited uses of the IWBT in delivering their courses or they did not seize the full potential of the IWBT. These are interesting propositions and worth further investigation.

The average age of the surveyed teachers is 44.5 years. On average they have been working in UAEU for 1.7 years. The majority of respondents to the survey were male (80%) and holders of PhD followed by master's degree (Table 3). The majority of ethnicities in the sample came from Arab countries followed by westerners and Emiratis respectively. Almost all respondents owned a laptop. However, the UAEU contributes to this result as it grants laptops to teaching-faculty in certain faculties (i.e., engineering, science, information technology). Teaching-faculty representation in the sample came largely from the teaching-faculty of science (26%) followed by the teaching-faculty of humanities (18%) and followed equally by both the teaching-faculty of business and economics and the teaching-faculty of engineering (16%). The following section highlights the research findings.

Interactive White Board Adoption

The research analyses followed an approach that classified the research findings according to respondents' ranking of the different items where results were discussed in the light of the highly (strongly agree) and poorly ranked (strongly disagree) measures. It is worth noting here that most responses were not extreme in the sense they were concentrated around the neutral position (between 2 and 4 Likert scale), and hence, most responses did not highly agree nor highly disagree with the different impacts of the IWBT in teaching in UAEU.

If we look at IWBT advantages, the findings are split into two parts. Table 4 shows the different characteristics that were highly ranked by respondents. Those advantages ranged from aspects relating to IWBT's features (visualized content, easy access to different resources at the same time, etc.) to aspects relating to the effectiveness of using IWBT in the classroom in UAEU (enhances the facilitation of learning, enhance the student's conceptual and practical understanding, etc.).

The second part (Table 5) shows the different characteristics that were ranked lower by respondents indicating having a lower impact on their IWBT teaching. It is observed that most of the measures in the table focused on assessing the IWBT as it is integrated with pedagogy and course content. Respondents did not feel strongly regarding such aspects. Interestingly, using the IWBT in

Smart Board Technology in Higher Education Institutions, Table 4 Higher-ranked advantages

#	Relative advantage	Mean	Std. deviation
Relating to IWBT's specifics			
1	Using the IWBT in the classroom offers more visualized content (graphics, colors, web sites, etc.)	3.61	1.188
2	The IWBT provides easy access to different resources at the same time in the classroom	3.50	1.140
3	The IWBT offers better features	3.48	1.159
4	The IWBT offers a better variety of teaching methods	3.36	1.120
5	Using the IWBT in the classroom offers more flexibility	3.26	1.245
IWBT's effectiveness in the class			
6	The IWBT allows the instructor to satisfy multiple learning needs within the one lesson	3.21	1.144
7	Using the IWBT in the classroom enhances the facilitation of learning	3.15	1.136
8	The IWBT enhances the preparation and the management of my class	3.13	1.129
9	Using the IWBT's different resources in the classroom enhance the student's conceptual understanding	3.05	1.145
10	Using the IWBT's different resources in the classroom enhance the student's practical understanding	3.01	1.124
11	The IWBT better relieves physical fatigue relating to teaching in the class	3.01	1.176

Smart Board Technology in Higher Education Institutions, Table 5 Low-ranked advantages

#	Low-ranked advantages	Mean	Std. deviation
1	The IWBT in the classroom provides better exercises and assessments	2.97	1.102
2	Using the IWBT in the classroom promotes learner-centered teaching	2.92	1.017
3	Using the IWBT in the classroom enhances idea sharing in the classroom	2.86	1.064
4	Using the IWBT in the classroom saves the instructor's time	2.86	1.361
5	Using the IWBT in the classroom increases instructor-to-student interactions	2.85	1.128
	Using the IWBT in the classroom provides better lesson participation from students	2.85	1.128
6	The IWBT gives me more time to face the class	2.83	1.286
7	I save notes made on the IWBT board for later use by me or students	2.79	1.149
8	Using the IWBT in the classroom promote positive social norms and habits	2.73	0.990
9	Using the IWBT in the classroom provide better collaboration between students	2.70	1.037
10	I post (e.g., email) saved notes made on the IWBT board to students	2.69	1.112
11	Using the IWBT in the classroom increases student-to-student interactions	2.63	1.043

the classroom did not seem to save the instructors' time or to give them more time to face the class.

As for IWBT challenges, Table 6 shows different challenges confronted by teaching-faculty inside the classroom. It is clear from the responses that teaching-faculty faced several technical difficulties in dealing with IWBT's software and hardware problems which require more specialized technical expertise to fix it. They reported that the IWBT fails more frequently during the class session and it takes longer time to repair. This is further compounded by the lack of support and maintenance for IWBT which limits their ability

to use the IWBT in the classroom. However, computer viruses did not seem to be a problem for IWBT usage in the classroom.

Interestingly, teaching-faculty noted that using and integrating course content with the IWBT in the classroom is an easy task for them. Also, they did not see learning about the different information technology resources in the classroom as difficult for them. However, given the above discussion, it was obvious that the IWBT here relates to using IWBT's obvious features only, i.e., as a projector, showing a web site, etc. The lack of digital educational materials to show the effective

Smart Board Technology in Higher Education Institutions, Table 6 IWBT challenges

#	IWBT challenges	Mean	Std. deviation
Higher rankings			
Technical problems			
1	The IWBT faces more software problems in the classroom	3.86	1.008
2	The IWBT requires more specialized technical expertise to fix it	3.82	1.000
3	The IWBT faces more hardware problems in the classroom	3.82	1.007
4	The IWBT takes longer time to repair	3.76	0.992
5	The IWBT fails more frequently during the class session	3.75	1.076
2	I would call a technician to fix a problem with the IWBT during the class session	3.54	1.080
6	The lack of support and maintenance limits my ability to use the IWBT in the classroom	3.29	1.071
IWBT usage and instructions			
1	I am using the basic functions of the IWBT in the classroom	3.77	0.835
2	Integrating my course content with the IWBT in the classroom is an easy task for me	3.38	1.010
8	There is a lack of digital educational materials to highlight the advantages of using the IWBT in the classroom	3.33	0.935
9	Using the IWBT in the classroom is easier for me	3.31	1.055
Lower rankings			
1	Computer viruses represent a problem for IWBT usage in the classroom	2.91	0.920
2	Learning about the different information technology resources for me in the classroom is difficult for me	2.32	1.032
16	I have enough time to fix problems with the IWBT during the class session	2.28	1.057

use of the IWBT in the classroom further endorses this opinion. Also, it could be used to justify the low usage of the advanced features of the IWBT by UAEU's teaching-faculty.

Using IWBT is a must in UAEU as there is no alternate technology in the classrooms. Table 7 shows some positive attitude toward IWBT among teaching-faculty. They are motivated to use the IWBT and its different multimedia resources, and they felt that IWBT fits with the way they teach. However, teaching-faculty noted slight drawback on IWBT usage such as in limiting their ability to exercise other teaching methods and styles inside the classroom, and this in turn deprived students from witnessing alternative styles. In this regard, teaching-faculty seemed to be confined to using IWBT's features only. Toward the low-ranked items, there was a weak support for the impact of the IWBT among teaching-faculty. Teaching-faculty barely agreed on having enough time to use IWBT's features in the classroom and that such features are more suitable to the course content that they teach in

the classroom. However, they did not foresee the IWBT to:

- a. Attract positive attention to them
- b. Motivate students to learn
- c. Be comfortable to them in terms of its position inside the classroom
- d. Effect personal contacts with students
- e. Allow for more time to face the class while teaching which allows them to maintain class control
- f. Give more time to be in touch with students by maintaining eye contact

In looking at the supporting environment, most of the factors in Table 8 seemed not to be supported in the case of the UAEU. Although some support was provided by management and in providing training on how to integrate the IWBT technology into the teaching processes, none of the remaining factors elevated beyond the cut-off (neutral) point. Those factors need to be addressed by UAEU management in order to realize IWBT advantages.

Smart Board Technology in Higher Education Institutions, Table 7 Teaching-faculty attitude toward IWBT

#		Mean	Std. deviation
Higher rankings			
3	I am motivated to use the IWBT in the classroom	3.32	1.065
4	I am comfortable dealing with the different multimedia resources accessed by the IWBT	3.24	0.975
5	I feel that I must use the IWBT in my teaching	3.12	1.075
	The IWBT fits with the way I like to teach in the classroom	3.10	1.114
6	I feel that using the IWBT in the classroom limits the exercise of other teaching methods and styles	3.10	1.024
7	Using the IWBT limits the students' ability to exercise other learning activities in the classroom	3.09	0.920
8	I have enough time to use the IWBT features in the classroom	3.07	1.130
9	IWBT features are more suitable to the course content that I teach in the classroom	3.06	1.083
Lower rankings			
10	Using the IWBT in the classroom attracts positive attention to me	3.00	1.022
11	Using the IWBT in the classroom motivates my students to learn	2.95	1.018
12	I am comfortable with the way the IWBT equipment are installed inside the classroom	2.90	1.108
13	Using the IWBT in the classroom could result in losing personal contacts with students	2.87	1.083
14	The IWBT allows for more time to face the class while teaching which allows me to maintain class control	2.86	1.067
15	The IWBT gives me more time to be in touch with students by maintaining eye contact	2.83	1.094

Smart Board Technology in Higher Education Institutions, Table 8 Management support

#	Management support	Mean	Std. deviation
1	The management supports the effective use of the IWBT in the classroom	3.18	0.898
2	The university/teaching-faculty provide sufficient technical training on how to integrate the IWBT technology into the teaching processes	3.05	1.050
3	The university/teaching-faculty provide sufficient teaching trainings on how to use the IWBT for teaching	2.99	1.043
4	The management is involved in the effective use of the IWBT in the classroom	2.98	0.893
5	The management leads the effective use of the IWBT in the classroom	2.95	0.918
6	The university/teaching-faculty have a clear plan for the effective use of the IWBT in the classroom	2.94	0.998
7	The management puts measures and procedures for the effective use of the IWBT in the classroom	2.89	0.898

Interactive White Board Implications

The research findings were in line with the literature. For example, Gursul and Tozmaz (2010) found modest (23%) use of IWBT in the classroom by teachers who reported using the IWBT as a combination of computer and projection; carrying out such interactive activities as matching, dragging, and painting; and using it for normal board activities (solving questions, writing, etc.).

Other advanced uses of IWBT were minimally reported by the same teachers.

IWBT is considered a disruptive technology as its full realization is dependent on its full integration in pedagogy. That is, pedagogy should drive IWBT not the opposite. In reality this represents a challenge for most educators in the world. This was evident in this research analyses and the challenges faced in interpreting the research results. Due to the lack of knowledge about the effective

use of IWBT and how to integrate it in teaching, the majority of responses were concentrated around the neutral level. The lack of support for the different factors in the research framework suggested the lack of IWBT integration in teaching in UAEU. Contradicting findings in this research further endorsed this posture. Conducting longitudinal research could monitor the progress on the impact of the different factors in this research on IWBT success.

However, this research was delimited to the specified factors in this research. This research used standard measures where possible in developing the survey questionnaire. Further, most of IT research looked at adoption as a proxy for IT success. However, attempting to capture the depth of the adoption criteria of IT or its use in business through dichotomous adoption (yes/no) measures is inconclusive. This research introduced both adoption and usage measures to assess the depth of IWBT penetration in pedagogy in UAEU. It is obvious that “usage” as a measure produces more effective results here as mere adoption is not an effective indication of IWBT success. Researchers could capitalize on this research’s framework and measures by adding further factors and measures which could shed more light into the IWBT phenomenon in tertiary teaching in UAEU and elsewhere.

If we look at IWBT advantages, the implications here are twofold. First, teaching-faculty commended IWBT’s most obvious and direct advantages only which represented an extension to existing technologies in the classrooms. In this regard, the IWBT represents a superior technology with its dual smart-boards and projectors, touchable screen, and integration with a computer and Internet to display online content. However, this admiration started to dwindle as the unique and more advanced aspects of the IWBT started to emerge. This finding led to a conclusion that IWBT is not yet integrated in teaching as such in UAEU. This conjuncture could be further endorsed by the finding that using the IWBT in the classroom did not promote positive social norms and habits. Also, the lack of digital educational materials to show the effective use of the IWBT in the classroom further endorses this opinion. Reasons for such attitudes and low-usage

could be attributed to lack of knowledge and resources on how to integrate and use IWBT’s advanced features to:

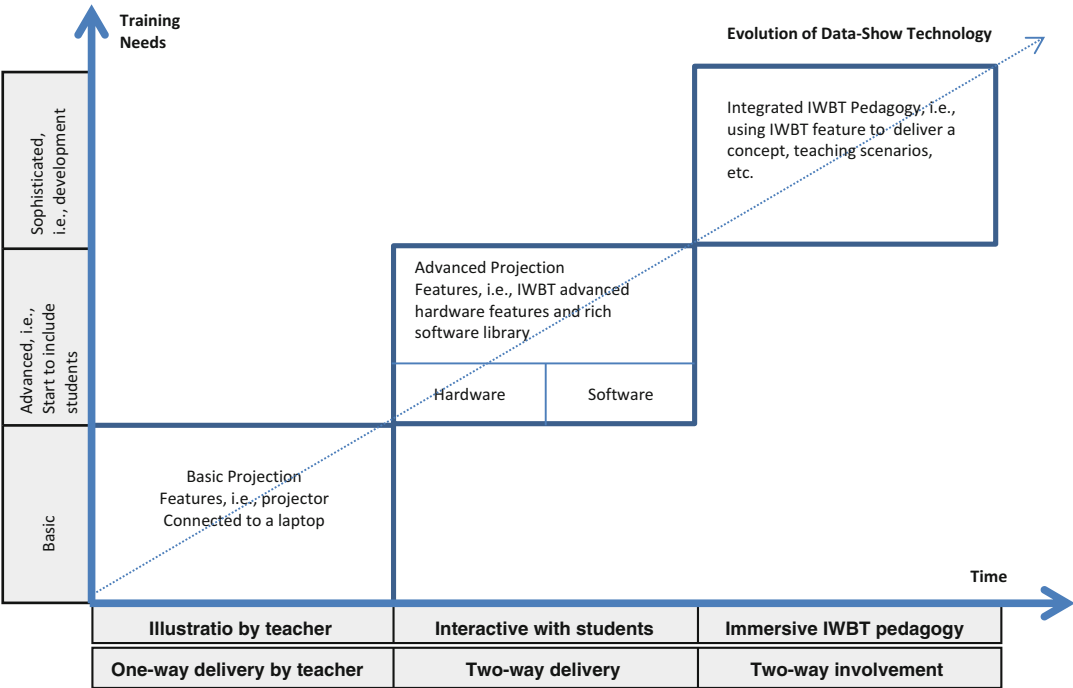
- a. Provide exercises and assessments
- b. Promote learner-centered teaching
- c. Promote idea sharing in the classroom
- d. Increase instructor-to-student interactions
- e. Increase student-to-student interactions
- f. Encourage lesson participation from students
- g. Provide better collaboration between students
- h. Integrate IWBT’s notes-taking into the course content

From the above remarks it is obvious that the process with IWBT is not that easy in UAEU as it requires the collaboration of technologists, educators, and students to fulfill such integrated tasks. One possible solution here is to form a committee that includes the above stakeholders to integrate IWBT’s features and curricula. Students’ involvement is important as they are the end recipients of such integration and their acceptance and satisfaction of the developed solution is essential.

To better illustrate the above insights, Fig. 1 shows the evolution of the data-show technology across time showing the position and the strength of IWBT as compared to existing technologies in the classroom. The figure also shows the direction of the industry trends and teaching strategy along with a depiction of the learning needs across each evolutionary phase. In this research it is suggested that UAEU is positioned in the middle of the evolutionary path in Fig. 1.

Technical mishaps that surrounded the IWBT in the classroom represent a great challenge for teachers wanting to finish their classes and course material on time. The implications here are three-fold. Initially, the IWBT is maturing and manufacturers are enhancing its features, reliability, and availability in the classroom. This is an important priority. Gursul and Tozmaz (2010) suggestions toward a more efficient use of IWBTs indicated that technical staff should be available in order to overcome technical problems.

Secondly, teachers must be trained at least to address most impending IWBT’s technical problems that may arise (impede) during a class session. The availability of technical staff on-site is



Smart Board Technology in Higher Education Institutions, Fig. 1 Evolution of the data-show industry across time

important to maintain the continued functionality of the IWBT inside the classroom. A better service level agreement (SLA) with vendors should guarantee effective on-site and off-site response and repair time and putting contingency measures and backup plans, in case a prolonged time is needed to fix a faulty IWBT or server (i.e., providing a backup or portable unit). Let's not forget that the installed IWBT in each class in UAEU has dual white boards and projectors which add some redundancy and class continuity in case of a failure.

The positive teaching-faculty's attitude toward IWBT represents a good starting point which should not be missed out by management. Gursul and Tozmaz (2010) suggested that corresponding authorities should provide digital educational materials that can be used on IWBT and qualified staff to help teachers use the IWBT more effectively and IWBT should be integrated into teachers' lesson plans. This has led to the research's third implication. The adoption and diffusion of IWBT in teaching in UAEU should not be automatic rather infused in a piece-meal fashion where it should supplement exciting

teaching preferences, approaches, tools and strategies first. Teaching-faculty noted that the IWBT deprived them from exercising other teaching methods and styles inside the classroom and this would reflect negatively on students. They also noted that they did not foresee the IWBT to be an effective management and control tool inside the class. Remedying such challenges is important before elevating to the next level. Here, plans for supplanting existing teaching approaches with IWBT should be drafted in the longer term projections alongside important behavioral aspects as highlighted in this research. This entails addressing cultural perspectives concerning teaching-faculty and students. Finally, IWBT usage by teachers should be monitored to report progress.

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Snap! Programming System

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Introduction

Snap! was developed by Jens Mönig and Brian Harvey under the umbrella of the University of California at Berkeley, with the objective of bringing the power of the Scheme programming

language and its computer science concepts into a Scratch-like environment. In fact, for a bunch of years, Snap! was developed as a modified version of Scratch. The ability to construct your own blocks out of other blocks was one of the foundational principles of this modification of Scratch, which is why, initially, they named it BYOB (standing for Build Your Own Blocks). In Snap!, blocks built by the user bear the same weight as any other preexisting ones. In other words, Snap! lets us build custom expressions that look and behave like primitive ones.

Nowadays, Snap! is a separate project with a codebase that is completely independent from Scratch and with an outstanding number of new features and particularities that make it suitable for a serious study of computer science as well as for research projects. However, Snap! still keeps intact everything that Scratch is about, and, in a programming language jargon style, we could very well call it a dialect of the latter.

So, before diving into what makes Snap! special, let us see what it inherits from Scratch and how it can be used for a playful introduction to programming and computer science.

What's Scratch-Like in Snap!

The User Interface

In the Snap! user interface, we quickly recognize three major column-shaped areas that resemble those in Scratch. The leftmost one is called the *palette*, and that is where we can find all the primitive expressions, in the shape of blocks. To build our programs, we will be dragging these blocks into the big, central area. This striped gray blank space at the center is called the *scripting area*, and it is where we combine these blocks together to give behavior to objects in the system.

Like in Scratch, this central column features three different tabs. Aside from the default one that we have just described, labeled *Scripts*, we can also choose between *Costumes* and *Sounds*. These two additional tabs let us deal with images that our objects can “wear” as costumes or sounds that our objects can play.

The third column is a very important one, and it is, in turn, divided into two rows. The white rectangle at the top right is what we call the *Stage*: a programmable microworld where our objects interact with each other (and with us) according to the code we have composed for them. When you first open the Snap! editor, the Stage only contains one arrowhead-shaped object, in homage to Logo, where the programmable *Turtle* was also represented as an arrow. We call these objects *sprites*, and we can see how many of them there are, what their names are, and a small thumbnail previewing what they look like at the bottom of the Stage, in an area we call the *corral*. At the center left of the corral, we can see a thumbnail of the Stage itself that can also be programmed.

Live, Parallel Blocks

Some block-based environments translate graphical blocks into text-based languages that are then fed into an interpreter or compiler. In that sense, these environments do not constitute actual programming languages but graphical, block-based façades for existing text-based languages. In such environments, we very often have to begin our programs with a predefined “start” block and run them by using some kind of “run” button or instruction.

One of the essential differences between these block-based language representations and Scratch (and thus) is that the latter does not translate blocks into any other language. Scratch and Snap! are full-fledged languages all by themselves, with an evaluator that actually looks up the graphical blocks and runs them in place.

This lets us build programs that have multiple start points and even run arbitrary pieces of code (block stacks) at our own will, whenever we want to. Clicking on a block or block stack will run it immediately, and if that block is meant to return a value, it will actually pop up a speech bubble showing that value. Scratch and Snap! are live also in the sense that we can modify code while it runs, without having to stop our scripts and restart them again to see these changes take effect.

Another key particularity of these languages lies in their parallel execution model, allowing us to run many processes at the same time. The evaluator

takes care of scheduling the execution of these processes for us and makes sure that – in the vast majority of the cases – we do not have to worry about race conditions, deadlocks, or any other quirks of concurrent programming.

Events

As explained in the previous subsection, processes can be started by just clicking on blocks and block stacks, and it is strongly encouraged to play with the language in that way, as it allows the programmer to experiment with code in an interactive way. However, sometimes we are going to need scripts to be triggered automatically upon given conditions, not just when we decide to click on them.

In languages like Scratch or Snap!, the way to bind scripts to events is to crown them with what we call a *hat block*. What these hat blocks do is to start whatever script is attached to them when the event in question occurs.

Examples of such events include pressing a key, moving the mouse, clicking on an object, receiving a broadcast message, or pressing a particular button in the user interface. Additionally, in Snap! we also have a generic “when” hat block that lets us define arbitrary trigger conditions for a script.

What Sets Snap! Apart from Scratch

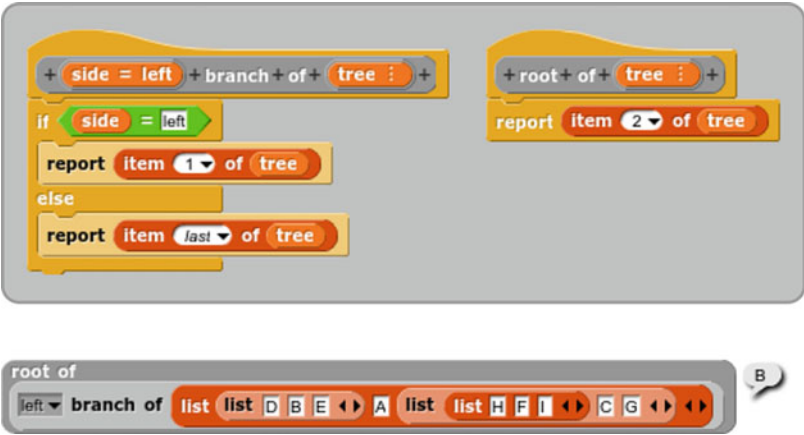
First-Class Heterogeneous Lists

Snap! takes from the Scheme programming language the idea of first-class lists as the only necessary complex data structure, out of which we can build any other data structure that we can imagine. When we say that something is first class, we mean that it can be used in the same way as any of the primitive data types in the system, such as a number or a string. This implies that, in Snap!, we can use lists as if they were, for example, numbers.

As such, we can assign lists to variables, use them as parameters to blocks, have functions return them, or broadcast and receive them as messages.

Since lists are first class, and since something that is first class can be used as if it was a simple

Snap! Programming System, Fig. 1 An example of a binary tree implementation. Top: definition of the branch and root accessor blocks. Bottom: example usage with a tree list



number, it must be possible to have lists contain other lists. In fact, by embedding lists inside of other lists is how we can compose any imaginable data type.

In order for this to work, though, we also need the language to let us store whatever we want into lists, be it a number, a string, another list, a block, or a sprite. That is, lists should be able to hold anything that the system exposes as first class. Not only that, but we need lists to be heterogeneous, meaning that we need to be able to store different data types all mixed together as elements of the same list.

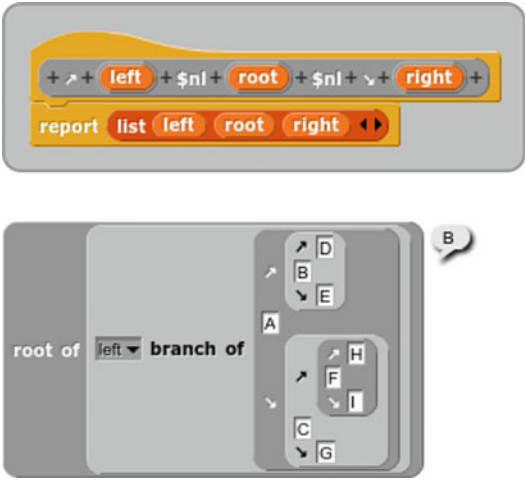
Having these properties we could, for instance, implement binary trees as lists where the first element holds the left branch of each node, the second element holds the root, and the third element holds the right branch (Fig. 1).

To make the tree structure easier to understand, we could build a block that hides away the internal list representation. Thanks to Snap!’s support for unicode characters and line breaks in block labels, we could even build a block that resembles a tree branch (Fig. 2).

Similarly, a stack could be implemented as a list where we can only either add a new element or retrieve (and remove) the latest element added (Fig. 3).

Associations can be thought of as lists where the first element is the key and the second element is the value, and thus dictionaries can be thought of as lists of associations (Fig. 4).

In a similar fashion, by just grouping elements into lists and building custom blocks that abstract



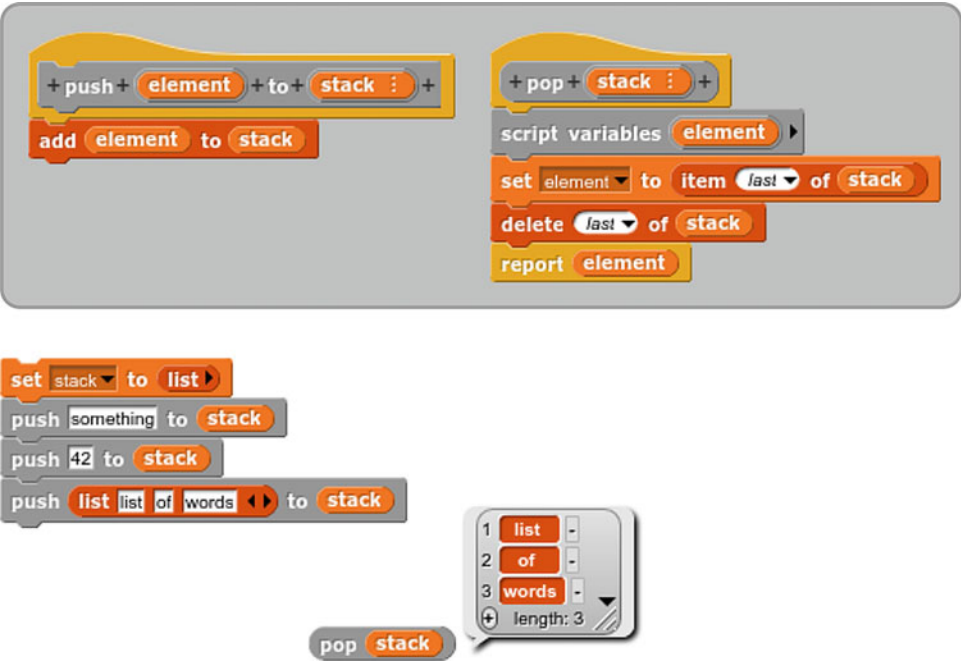
Snap! Programming System, Fig. 2 A more visually appealing tree representation. Top: definition of the tree block. Bottom: example usage

away the complexity of these structures, we can implement any other data structure, be it a heap, a hash table, or a set (Fig. 5).

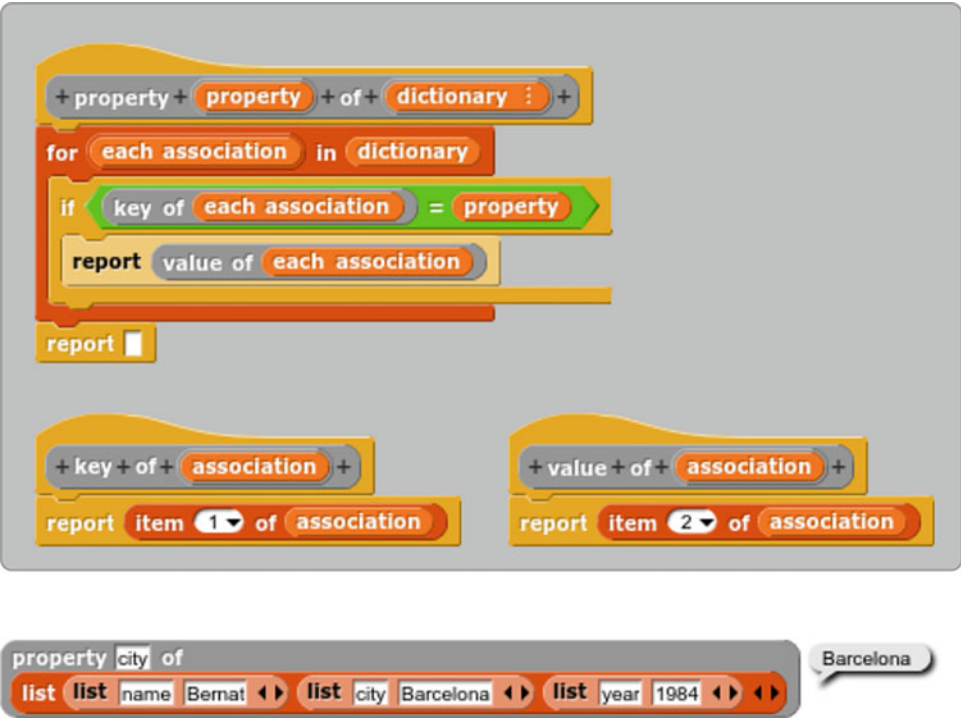
Tables

Snap! offers two different visual representations of lists. The first one is box-shaped and displays all items contained in the list sequentially from top to bottom. This representation reflects changes to the list contents in real time, making it very useful for live inspection of objects and data structures (Fig. 6).

The second representation is the default one for lists of lists where the first inner lists have more

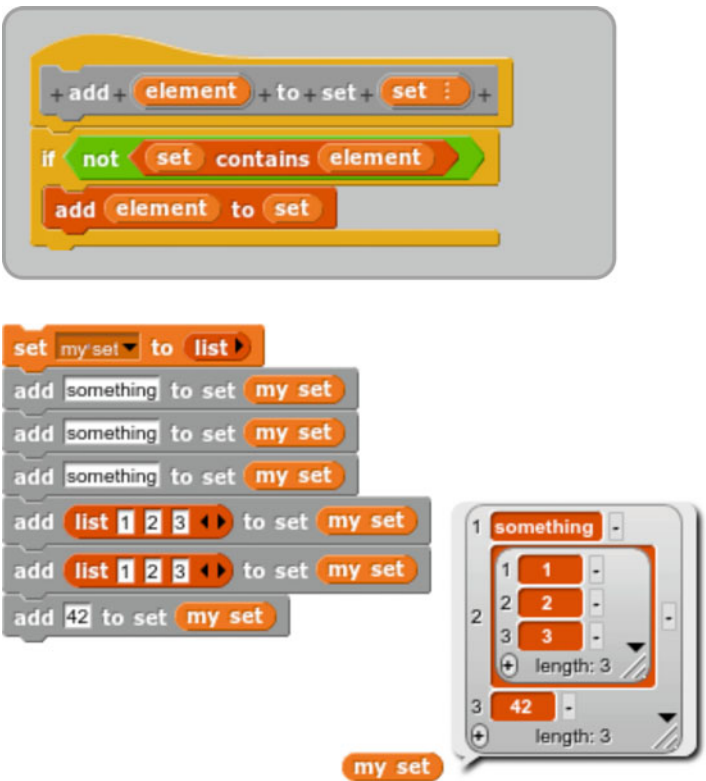


Snap! Programming System, Fig. 3 A possible stack implementation. Top: definition of the push and pop blocks. Bottom: creating and filling a stack with some elements and popping the last one



Snap! Programming System, Fig. 4 Dictionary data structure. Top: implementation of the key, value, and property accessors. Bottom: looking up the property “city” in a dictionary with three associations

Snap! Programming System, Fig. 5 Example set implementation. Top: definition of a block that adds elements to a set. Bottom: trying out the new block and confirming it does not allow any duplicates



Snap! Programming System, Fig. 6 Traditional list representation



than two items. This representation is not live, so changes to the original objects are not reflected in real time, but it is extremely fast and is capable of displaying hundreds of thousands of rows with almost no performance penalty, which makes it suitable for inspecting big data sets and very long collections (Fig. 7).

First-Class Procedures

One of the main foundational ideas behind Snap! is to let the programmer extend the system by

building blocks that look and behave exactly like the ones provided by default. We have already seen examples of new block definitions in the previous section, when implementing different data structures, but we have not explained them in detail.

To create a new block in Snap!, we need to either head to the *Variables* category and click on the *Make a block* button or right click (command-click on MacOSX) anywhere in the scripting pane and select *Make a block* from the contextual menu.

51096	A	B	C
29699	13.167	13.515	19.478
29700	13.167	22.760	-8.413
29701	13.167	40.553	-23.381
29702	13.167	47.460	-22.445
29703	13.170	-12.486	22.396
29704	13.171	17.586	0.467
29705	13.175	47.490	-17.131
29706	13.178	-27.679	20.058
29707	13.178	23.012	-8.666
29708	13.179	-38.655	34.414
29709	13.179	7.592	22.348
29710	13.182	27.132	-12.199
29711	13.182	35.833	-14.275
29712	13.183	5.491	22.540
29713	13.185	-19.876	20.893
29714	13.185	17.397	18.020
29715	13.186	-28.474	20.197
29716	13.186	15.073	19.032
29717	13.186	18.752	14.897
29718	13.189	18.790	16.310
29719	13.190	29.371	-13.306

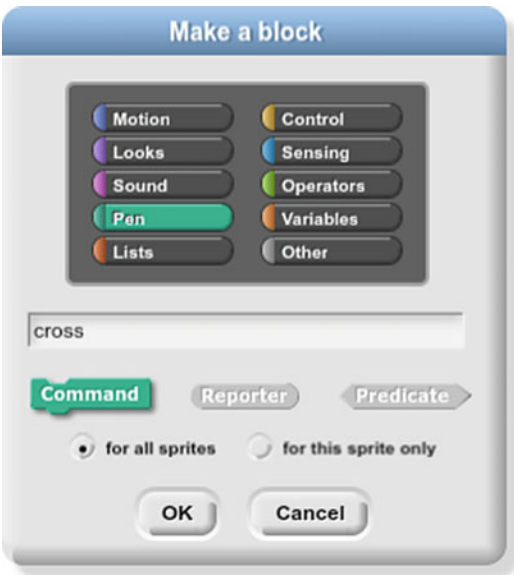
Snap! Programming System, Fig. 7 Tabular representation of a huge list of 51.096 rows where each row is a list containing three numbers

This will open a dialog where we will be asked to select a category and give a name to the new block. Additionally, we will be able to choose among three different kinds of blocks, namely, commands, reporters, or predicates.

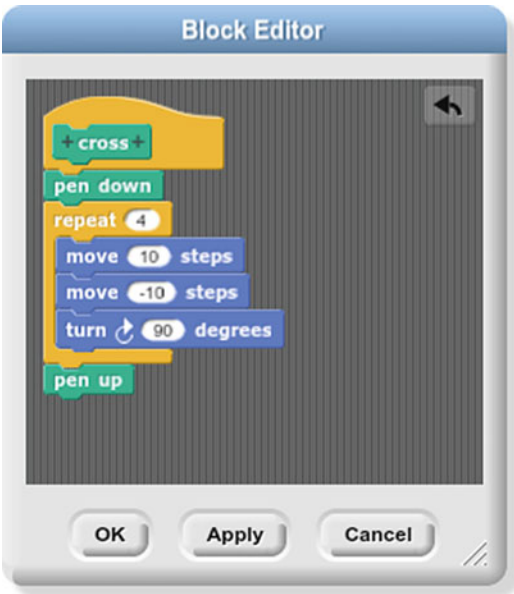
Command blocks are the ones that can be stacked to other blocks. They are called commands because they perform an action. Reporters, on the other hand, are blocks that can be embedded into input slots of other blocks, and they return values. Predicates are a particular case of reporters, in particular the kind that returns a Boolean value.

As an example, we will be creating a new block that draws a cross, and we will place it under the *Pen* category. Since this block performs an action, it will be a command block, and since we want every sprite in the project to be able to run it, we will select *for all sprites* (Fig. 8).

Accepting this dialog will show another dialog where we can define our block (Fig. 9).



Snap! Programming System, Fig. 8 Creating a new *cross* global command block under the *Pen* category



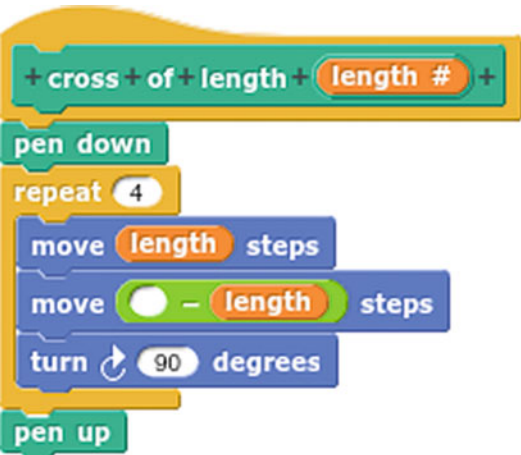
Snap! Programming System, Fig. 9 The *cross* block sets the pen down, moves the sprite in a cross pattern, and then sets the pen back up again

Blocks in Snap! can have parameters, which we can use to modify their behavior accordingly. We could, for instance, add a *length* argument to the *cross* block that defines how long the four

arms of the resulting cross drawing are. To do so, we need to edit the block by selecting *edit* from its contextual menu (right-click on the block for GNU/Linux or Windows users and command-click for MacOSX users) and then add the missing text and parameters by using the little plus-sign-shaped buttons on the block label (Fig. 10).

This new block can be now used as if it was any other block in the system and will be graphically and functionally indistinguishable from the native ones (Fig. 11).

Custom blocks being first class means that we can also use them to define other custom blocks or even to define themselves recursively. That allows us to build a new *fractal cross* block that makes use of itself to draw a fractal cross figure, where each arm ends in a cross half the size of the previous one and results in a square pattern (Fig. 12).

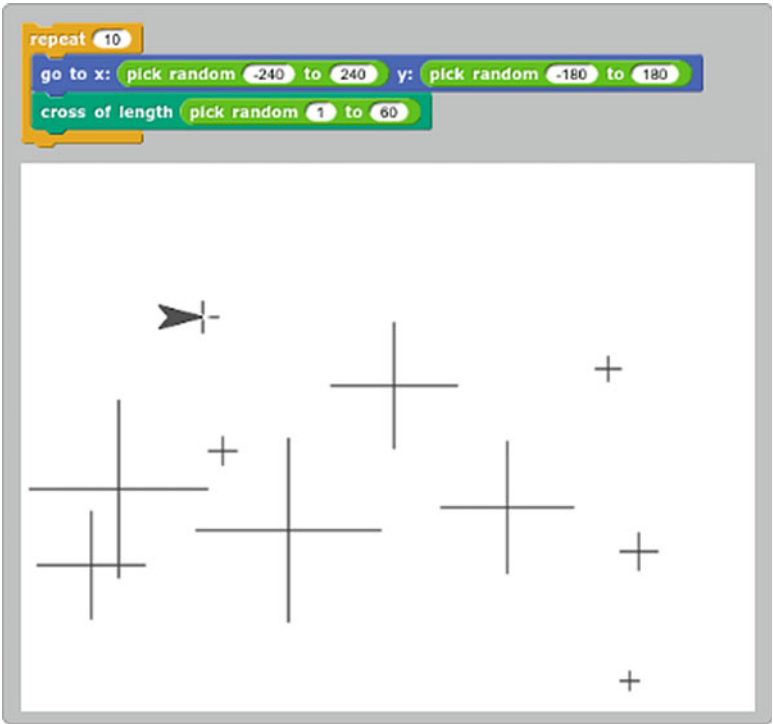


Snap! Programming System, Fig. 10 The new *cross* block definition, after having added a new *of length* text part and a *length* parameter to it. The pound symbol next to the parameter indicates that we are expecting it to be a number

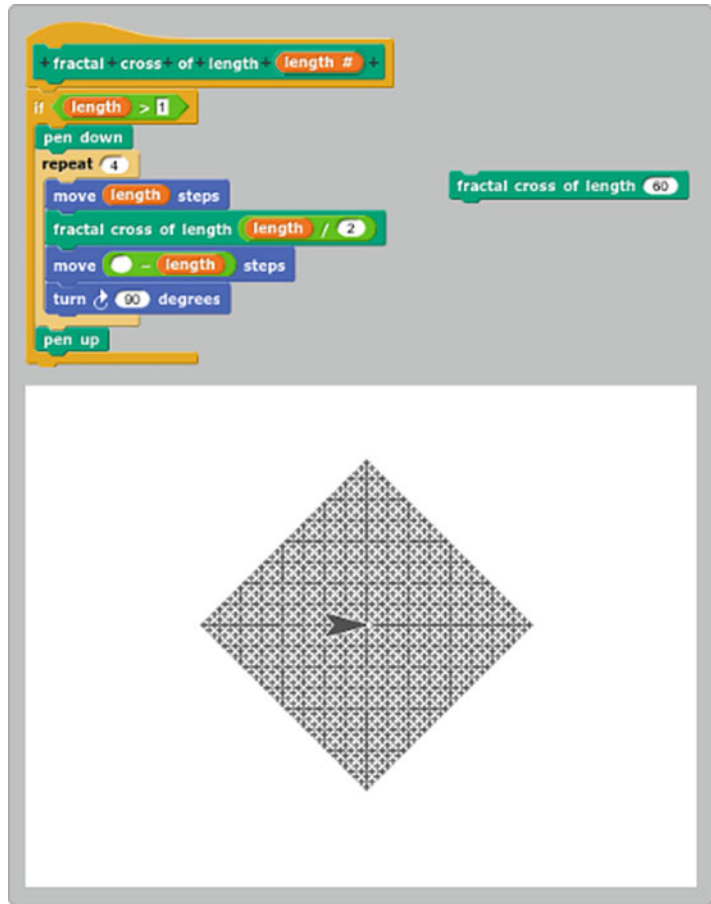
Closures

Closures are programming constructs that allow us to deal with code as if it was data. *Full closures*

Snap! Programming System, Fig. 11 The *cross* block being used to draw crosses of random arm length



Snap! Programming System, Fig. 12 The new *fractal cross* block definition, plus an example of the drawing it generates when used with an arm length of 60



capture the context in which they are created, including the values of any variables in their scope. A full closure is, in a way, like taking a snapshot of a piece of code at a particular moment in time, so that invoking that closure later on will be like running it at the moment of its creation, including the state of the program at that past moment.

This lets us play with code in a substantially different way, even allowing us to define our own control structures. In fact, some computer languages – like Smalltalk – implement all of their control structures by means of closures, without the need of any primitive expressions or reserved keywords.

Snap! represents closures as *ring blocks*. A ring is a special graphical structure that encloses scripts and turns them into first-class data (Fig. 13).

A *ring* is, actually, a procedure without a name, and clicking on the right-pointing arrow on its



Snap! Programming System, Fig. 13 A *ringified* addition block



Snap! Programming System, Fig. 14 A *ringified* addition block with a parameter

right edge will let us add parameters to this procedure (Fig. 14).

But these procedures are special in that clicking on them will not result in them running. As explained before, these constructs convert code into data, so clicking on them will actually just return the data they hold (i.e., the closure

itself). In other words, if we understand procedures as verbs, then putting a ring around a verb is turning it into a noun.

To run these, we need to use one of the two special blocks Snap! provides, namely, *run* and *call*. The first one is meant to be used to execute a ring as if it was a command block, whereas the second one will execute it as if it was a reporter. That is, the second one – *call* – will expect the ring to return a value (Fig. 15).

We have just created an anonymous procedure that adds 1 to any number, but up to here it seems that rings only add complexity to something we could have very much easily achieved by just using the addition block by itself, so let us find an example that shows the value of closures a little bit better.

Rings turn any stack of blocks into a parametrizable function that can be treated as data and, as such, can be passed to another procedure as a parameter, in the same way that we can pass a number, a string, or a Boolean as a parameter. This allows us to, for instance, map the items of a list into a new list where each item has been applied a

function, without the need of using any iterators or indexes. From a mathematical point of view, this could be seen as the application of a function over a vector (Fig. 16).

As a little syntax sugar goodie, Snap! will automatically fill up any empty input inside the body of a ring, letting us rewrite the previous code in a shorter form with exactly the same functionality (Fig. 17).

This automatic parameter filling lets us easily map a list into another list where each item maps to its own double (Fig. 18).

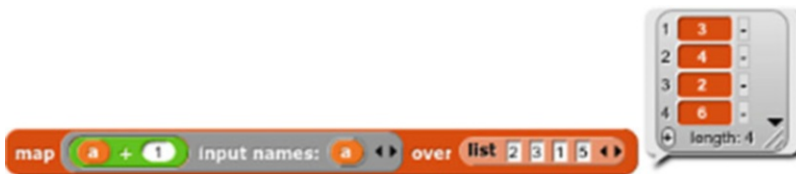
As a matter of fact, the *map* block is actually implemented in Snap! itself, and, internally, it takes a function as a parameter and iterates over a list to apply that function to each of its items (Fig. 19).

As a curiosity, even the *for each* block used inside the *map* block has been implemented as a custom block that takes a function as a parameter and runs it for each item in a list (Fig. 20).

These functions that take other functions as parameters and apply them to every item on a list are called *higher-order functions*, and they



Snap! Programming System, Fig. 15 Calling the ringified addition block with one parameters and getting back the result the adding 1 to that parameter



Snap! Programming System, Fig. 16 Mapping the *add 1* anonymous procedure to a list and getting back a new list where each item has been incremented by 1

Snap! Programming System, Fig. 17 The same application of map over a list but this time with automatic parameter filling



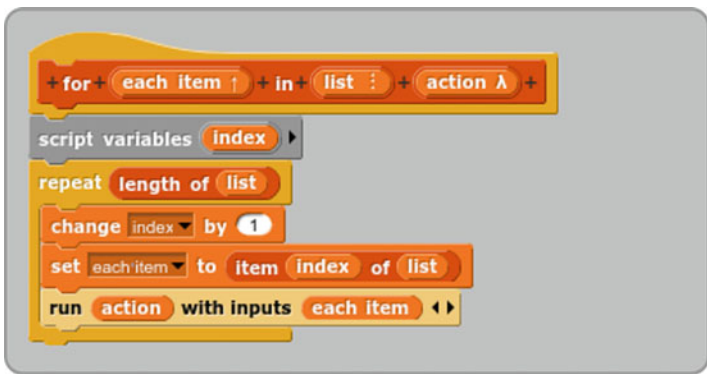
Snap! Programming System, Fig. 18 Using the automatic parameter filling feature to double all numbers in a list



Snap! Programming System, Fig. 19 A simple, iterative implementation of the *map* block



Snap! Programming System, Fig. 20 A simple, iterative implementation of the *for each* block



represent one of the most useful applications of closures in computer science. Indexes and iterations are processes that are much closer to the way computers work than to the way humans think, which is why, in functional programming, *HOFs* are the natural way to transform lists and perform operations over their items.

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<https://snap.berkeley.edu/>
[https://en.wikipedia.org/wiki/Snap!_\(programming_language\)](https://en.wikipedia.org/wiki/Snap!_(programming_language))

Social and Collaborative Technology

- ▶ [Assisting Students with Learning Disabilities Through Technology](#)

Social Constructivism

- ▶ [Collaborative Learning and Patterns of Practice](#)

Social Effects of the Application of Data Science Methods

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Social Media

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Social Media and Networks as Digital Instruction and Learning Platforms

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Introduction

Mobile learning is an evolving technology that utilizes the advancements in mobile computing to enhance education. In mobile learning portable devices such as laptops, tablets, iPads, and smartphones are used as platforms for presenting learning content using Internet-based databases.

The widespread popularity and availability of mobile devices have led to the development of mobile learning as a legitimate delivery platform in the educational process, and mobile learning provides a range of platforms and opportunities for teachers and students in interactive learning environments. Knowledge is no longer confined to classrooms, and it is now possible, feasible, and sensible to provide learners with access to knowledge via mobile learning without the constraints of time and location (following Neumann 2015).

Smartphones are now universally accessible and have become an integral part of daily life. In a recent report published by the Group Special Mobile Association (GSMA) in 2017, there will be an additional one billion subscribers by 2020. This trend is not only evident in the developed world but is characterizing the developing nations as well. In Asia, the Middle East, and North Africa, mobile penetration reached 50.2% in 2014 and expected to rise to 54.3% by end of 2020. In education smartphones are becoming increasingly popular among students (Domingo and Gargante 2016) and have proven to be successful in classroom utilization. Adolescent and young adult students increasingly view traditional learning platforms as somewhat boring and uninteresting; thus smartphones increasingly serve as valid alternative digital instructional educational platforms. In fact, the younger generations of students are more open and keen to embrace smartphones in the learning process (following Katz 2018).

Social Networks and Learning

Most students today are part of the Net Generation, sometimes called the Millennial Generation. This group of students has grown up with information technology all around them and is adept at social networking. They learn and communicate using technology, and as such, they expect their teachers to integrate technology into the classroom learning process. Mobile learning via smartphones is the popular and preferred technological platform for utilization of social

networks although laptops, tablets, and iPads can also be effectively used for mobile learning. Social networks may be defined as applications that enable users to communicate with each other by posting information, comments, messages, images, etc. Education and learning are perceived to be specific domains that can greatly benefit from social networks, and recent studies have indicated the increasing effectiveness of the contribution of social networks to the learning process. Social networks can support learning in general and, more particularly, problem-solving, communication, and collaboration with teachers and peers. Social networks represent a common space where friends can share information that can be viewed by others. Studies have shown that students spend a significant amount of time on social networks, checking and engaging in a variety of activities. Thus, social networks, coupled with appropriate pedagogical methods, have the potential to promote learning in educational frameworks and settings. Research results have intimated that social networks as educational tools in the academic landscape are catching on fast as colleges recognize the potential to use the networks for learning and learning via social networking is positively received by university students and contributes to the enhancement of student performance in the learning process. Social networks afford ample and potentially effective opportunities to improve student learning at elementary and secondary schools as well as university levels (following Katz 2014; Raspopovic et al. 2017).

In sum it may be said that research literature offers increasingly widespread evidence that supports the notion that social networks contribute to the fostering of student learning at all educational levels. In the following paragraphs, the different social networks commonly utilized in the learning process will be presented.

Social Networks as Learning Delivery Platforms

Social networks may be defined as technology-based applications that utilize mobile learning

technology to enable users to communicate on any number of topics. Recent studies have indicated that the field of education is a specific domain that can greatly benefit from the utilization of social networks in as well as out of the classroom. Learning is a social process of acquiring knowledge developed by individuals. The interaction between learners has been shown to enhance students' learning capacities. Thus, social networks within which people communicate and interact can contribute to the learning process by expanding the possibilities of learners to interact with their teachers as well as with their peers, thereby reaching new sources of information. Social networks as educational tools are catching on fast as universities, colleges, and schools recognize the potential that they have for the learning process. Research results have indicated that learning via social networking is positively received by students and contributes to an enhancement of student performance in the learning process and positively stimulates learning activities (following Katz 2014; Alkhathlan and Al-Daraiseh 2017).

In summary it may be said that research literature offers increasing evidence that supports the notion that social networks contribute to the fostering of student learning at the university, college, and high school levels.

SMS as a Learning Delivery Platform

As mobile technologies have developed, smartphones are increasingly being used as a learning platform. SMS messaging is used pervasively among students who are increasingly willing to use text messaging for educational purposes. This willingness to adopt text messaging for educational purposes involves a shift in perception on the part of most students who use these platforms primarily for social purposes. Thus, text messaging, together with students' willingness to use such technologies for academic purposes, has motivated authorities in universities and schools to implement SMS messaging to students' smartphones as a legitimate learning delivery strategy. Research results have indicated that when students receive text messages from a teacher, they feel more connected and think

more positively about the teacher and classroom activities. In addition, the use of SMS text messaging facilitates a more intimate student-teacher relationship, and text messaging strengthens social ties between groups of students for academic purposes (following Katz 2014).

Mobile-assisted language learning (MALL) via smartphone-based SMS delivery is rapidly becoming a legitimate and effective platform for vocabulary learning, and results of research studies have indicated that SMS delivery of vocabulary has a more significant effect on students' vocabulary retention than traditional instruction based on the use of dictionaries. In addition empirical results confirm that students who study language via SMS delivery are more enthusiastic about their learning of language idioms and attained higher scores on an achievement test than their counterparts who studied idioms by traditional teaching methods. Also, students who received English vocabulary lessons through the medium of SMS delivery performed significantly better on a vocabulary achievement test than students who received their vocabulary lessons by way of traditional face-to-face instruction. It has been suggested that the extra exposure to language and the reliance on phonological awareness and retrieval to compose and read text messages may explain positive, reciprocal relations between SMS text messaging and developing literacy (following Katz 2014; Ouellette and Michaud 2016).

In sum it is becoming increasingly clear that smartphone-based SMS messaging is rapidly infiltrating the educational process in universities and schools and is becoming commonly legitimized as an effective delivery platform for learning in general and for language learning in particular.

WhatsApp as a Learning Delivery Platform

Another social network application associated with mobile technology is WhatsApp instant messaging. Results of research studies have indicated that the WhatsApp application has a positive impact on learning success and its use is substantially welcomed by students in universities and schools. Students favor the use of smartphone-

based WhatsApp learning delivery in comparison to other types of social networking applications that serve as learning delivery and management platforms. WhatsApp delivery platform has the power to enhance students' learning and is a user-friendly mobile application that contributes to the promotion of learning and student satisfaction with the learning process. Students who used WhatsApp as a smartphone-based learning delivery platform improved their reading and writing skills, and the use of WhatsApp as a learning tool increases student curiosity and motivation in the learning process. In addition, students who used WhatsApp in the learning process enhanced interaction with their peers, fostered rich dialogue in the learning situation, increased sharing of knowledge among learners, and created an enjoyable collaborative atmosphere with peers. Research results have confirmed that different social network tools, but most especially WhatsApp, are advantageous in the learning process because of the integration of learning as well as social interaction in the classroom.

Results of recent empirical studies have indicated that WhatsApp provides students with an opportunity to express themselves freely in a non-limited environment thus eliminating the relatively low active involvement of students characterizing classroom lectures. WhatsApp technology also improves learners' active classroom involvement in learning. In addition, WhatsApp facilitates the creation of a positive social environment, develops a sense of belonging and community among students, and enhances dialogue between the students and teachers as well as between students and their peers to enable them to share information and operate as a team. Students are able to support each other by answering each other's questions and sharing their findings. Moreover, the utilization of WhatsApp has been shown to increase the accessibility of learning materials that enrich learning activities (following Katz 2014; Awada 2016).

From the above evidence, we may conclude that WhatsApp use as a learning delivery platform can effectively enhance learning as well as

collaboration and cooperation in the university or school classroom.

Facebook as a Learning Delivery Platform

Facebook, in addition to being the most popular social network for social groups, has also become a mobile learning-based learning resource well-suited to use with smartphones. From the results of numerous research studies, it is apparent that students value Facebook for providing an informal and motivating learning environment and that learning via Facebook delivery enhances learning performance of students. In addition, there is a clear indication about the positive potential of Facebook as a learning delivery platform at the school and university levels. When used as a learning delivery platform, Facebook enhances critical collaborative thinking, analytical thinking, and learning motivation as well as student-centered and social learning. There are empirical research indications that Facebook-based learning facilitates language learning as well as the learning of historical and cultural concepts. From the social point of view, there are indications that Facebook learning delivery leads to the narrowing of social gaps between students studying in more elite and less elite schools (following Katz 2018).

Results of recent research studies have also confirmed that the use of Facebook as a learning delivery platform leads to a higher level of student engagement with emphasis on increased student interaction with teachers as well as with peers. In addition, Facebook provides students with a way of maintaining and strengthening social ties, which are beneficial in academic settings. Similarly, the inclusion of Facebook in educational settings at one and the same time (a) enhances personally significant approaches to learning and self-expression in learning and (b) encourages students to build social connections that facilitate collaborative and peer learning. Facebook-based learning delivery also enhances student motivation and satisfaction with the learning process (following Carmichael and MacEachen 2017).

Thus, it appears that Facebook can serve as a reliable mainstream learning delivery platform

that positively contributes to students' academic attainments and at the same time uses social interactions between students and their peers as well as between students and their teachers to enhance their all-round performance.

Twitter as a Learning Delivery Platform

Twitter is another mobile-based technological application that may be defined as an online social networking service on which users post and interact with messages known as tweets. Tweets were originally restricted to 140 characters which limited its viability as a learning delivery platform, but in November 2017, this limit was doubled for most languages, thereby increasing the suitability of Twitter as a learning delivery platform. Users access Twitter through its website interface and use their mobile smartphones as receivers of the Twitter tweets. Twitter has increasingly become a mobile technology introduced into education as a learning delivery platform. Recent research suggests that within an academic environment, the use of Twitter adds to educational community building by offering students and teachers the ability to continually inform each other about what they are learning, discovering, or experiencing. Numerous studies have examined the utilization of Twitter in academic environments. Research results have indicated that the use of Twitter as a learning delivery platform can be responsive to student's learning needs. Specifically, Twitter can change classroom dynamics and significantly enhance the sharing of information. In addition, the use of Twitter can support learning beyond the traditional classroom through a constant flow of information between students and between students and teachers without limitation of time or location. Empirical research findings have confirmed that Twitter can serve as a powerful tool for enhancing social presence in addition to establishing informal, free-flowing communication between and among students and teachers. Furthermore, Twitter can help increase understanding of course materials as supported by the interactive environment and affiliated rapid feedback (following Thoms and Eryilmaz 2015).

There is increasing evidence that the use of Twitter in university courses as well as in the school classroom enhances students' learning capacity and potential. Research results have indicated that the use of Twitter at the university and high school levels enhances learning collaboration among students, increases learning curiosity and motivation, encourages students feel that learning could be trendy and fun, and focuses the attention of students on the topic under study. Additionally, empirical research results have confirmed that the use of Twitter for learning delivery leads to a positive effect on students' achievement as well as enhances students' willingness and desire to engage in learning tasks (following Katz 2018).

Thus, it appears that Twitter is an efficient mobile social network application that can positively promote student learning, student achievement, student curiosity and motivation, and student social interactions.

Affective Attitudinal Variables and Social Network Learning

Affective attitudinal variables, such as perceptions of user-friendliness, learner curiosity, learner motivation, and learner satisfaction, are some of those empirically known to be positively related to enhanced learning delivered via social network-based delivery platforms. Numerous research studies have indicated that the SMS-based, WhatsApp-based, Facebook-based, and Twitter-based learning delivery platforms are perceived by students to be more user-friendly than are more traditional learning delivery strategies. Recent research results have also testified to the positive significant relationship between learning achievement attained by students who utilized SMS, WhatsApp, Facebook, and Twitter delivery of learning and positive feelings of learner curiosity, learner motivation, and learner satisfaction with the learning process as perceived by these students (following Katz 2014, 2018).

Thus, it appears that when used in the educational process, the abovementioned social

networks indeed contribute to students' all-round performance which includes enhanced learning achievement as well the promotion of positive affective perceptions associated with their learning.

Conclusion

The empirical research results presented above indicate the potential of social networks as legitimate mobile learning delivery platforms. The four different social networks addressed (SMS, WhatsApp, Facebook, and Twitter) have been shown to yield a similar (but not identical) positive contribution to enhanced academic and scholastic achievement in universities and schools. In addition, the four social networks have also been shown to enhance students' perceptions of the user-friendliness of the learning delivery platforms as well as to encourage learner curiosity, learner motivation, and learner satisfaction with the learning process when compared to more traditional classroom-based learning delivery platforms. The present study indicates the potential of social networks as learning delivery platforms at the university level, and university policy-makers are urged to take note of this significant technological development.

The empirical results that indicate that social networks such as SMS, WhatsApp, Facebook, and Twitter learning delivery platforms contribute to positive learning and to positive affective feelings have led to the increasing introduction of these mobile-based applications into the repertoire of learning delivery platforms available for students in universities and schools. One may conclude that social networks have the proven potential to be utilized as legitimate learning delivery platforms that are competently able to enhance both cognitive and affective correlates of all-round student performance. Thus, the time is ripe for educational authorities to acknowledge the viability of social network applications such as SMS, WhatsApp, Facebook, and Twitter as acceptable learning delivery platforms at the university and school levels and seriously

consider the mass introduction of these mobile learning applications into the mainstream educational process.

Cross-References

- [Collaboration and Social Networking](#)
- [Social Media for Tertiary Education](#)
- [Social Networking in Higher Education](#)

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Social Media for Tertiary Education

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Synonyms

[Online social networks](#); [Social media](#); [Social networking sites](#); [Social platforms](#); [Social technologies](#); [Social websites](#)

Introduction

Technology has facilitated the rediscovery of traditional teaching methods by incorporating pedagogically useful features in a multidimensional environment. A by-product of the advancement in technology is social media – a dominant social interaction technology that has a plethora of uses. Social media can take different forms encompassing blogs, discussion forums, wikis, video-sharing sites, photo-sharing sites, social bookmarking, and social networking sites. Social media can be defined as a web-based technological platform for online communication that enables users to connect and interact, share ideas and information, build and engage social networks, and develop online communities. To maintain consistency, the term social media in this entry relates to all its different forms, unless explicit platform names have been used.

Social media has reshaped the way people communicate and interact, and its influence has not escaped the tertiary education sector. With smartphones and other mobile computing devices in easy access, the ubiquity of social media has increased. Social media platforms such as Facebook, Twitter, Google+, YouTube, Instagram, and LinkedIn are increasingly used to connect the community of learners and teachers. It

can be argued that people live on social media as teens and young adults worldwide spend an average of 188 minutes daily on social media (Statista 2017). If students are spending 3 hours a day on social media, then educators should consider reshaping their pedagogical practices and approaches to reach out to them via social media. Due to the significance of tertiary education or higher education in societies globally, and the amount of time students spend on social media, this nexus deserves attention, particularly with a view to seeing how social media can be used in tertiary education. Social media provides pedagogical, social, and technological benefits and has the potential to be widely utilized in higher education (Chugh and Ruhi 2018).

In order to harness the power of social media, it is crucial that educators understand its lacunae and forte. A one-size-fits-all solution may not be possible or advisable, especially when educational outcomes need to focus on curriculum, content, and collaboration. From an educational context, social media can undoubtedly prove to be a trusted platform for information dissemination, sharing and interaction, and easy accessibility to educational content. The role of social media in the education sector is not just limited to an educational context (teaching and learning), but it also plays a vital role in marketing, promotion, and generally reaching out to students via updates and announcements. However, the main focus of this entry revolves around the role of social media as a tool for teaching and learning activities.

In the pursuit to address this main focus, this entry first considers the benefits of social media for tertiary education. It then outlines some uses of social media for tertiary education. This is followed by the challenges of social media for tertiary education. Guidelines for social media usage in tertiary education are then outlined. Finally, the key premises of the entry are summarized.

Benefits of Social Media for Tertiary Education

For students, social media is an exciting and captivating tool that has opened doors to a wealth of

information, including huge networking opportunities and, above all, convenient access. Students appear to spend a lot of their time on social media. Thus, incorporating social media into teaching and learning practice and diverting the attention from casual socializing and gaming to social learning could prove to be valuable. Through a review of the literature, Tess (2013) highlighted that the majority of studies on social media usage in higher education classes had reported more positive than negative consequences for students. Students have a positive perception of using social media to enhance teaching and learning activities (Balakrishnan et al. 2017), and the use of social media technologies has also shown to increase academic performance of distance education students (Arif and Kanwal 2016). Social media use, as well as teachers messaging students, improved relationships and connections between students and staff, leading to improved class attendance and higher rates of completion (Callan and Johnston 2017). Social media can also facilitate distance learning by providing easier access to subject content in a variety of formats. As students are expected to conduct some form of research during their studies, social media gives them access to a wide range of information, often in a quicker way than traditional research methods. Social media platforms also enable students to consult others who have done similar projects or interact with experts across the world.

Essentially, education is a social process, and social media enables the process further by allowing students and teachers to interact, engage, and learn without worrying about geographic distance. Social media is also about staying connected. Having continuous access to online classes and staying connected to lecturers, tutors, and peers facilitates access to information when needed even when the students are away from traditional classrooms. Teachers use social media platforms with the aim of facilitating the learning process. Social media increases student collaboration and interactivity and enhances interaction between students and teachers (Sugimoto et al. 2015). Usage of social media for teaching and learning activities has also shown to increase trust between students and teaching staff (Ossiansson 2010). Social media allows students to

voice their opinion freely. This works in favor of students who are shy and often not confident in expressing their opinion in person. This also implies that introverted students are not disadvantaged.

Social media is also a valuable marketing recruitment tool that aids students in the educational decision-making process (Galan et al. 2015). Social media enables tertiary educational organizations to provide easy access to a variety of information about student life, university events, unit and program offerings, job opportunities, and so forth. All this information is used by students when they are evaluating study alternatives. The benefits realized through the use of social media in the facilitation of the recruitment process equally apply both to students and staff, as staff may be searching for similar information when applying for jobs. Social media is also used to enhance the interactions of alumni with their host institution. The interaction process is helpful not only in keeping alumni connected but also for fundraising and mentorship opportunities.

Uses of Social Media for Tertiary Education

In the context of teaching and learning, previous studies have outlined that social media has many uses, which includes, but are not limited to, engagement and reflective learning (Joshi and Chugh 2009); developing new literacy practices through text-making (Davies 2012); building social connections (Galan et al. 2015); delivering prior reading material for online interaction and in preparation for in-class discussion (Dyson et al. 2015) and academic-related activities (Khan et al. 2016); informing students about subjects, schedule changes, and resource requirements (Callan and Johnston 2017); and communicating with teachers and peers (Evans 2014). This demonstrates that social media provides numerous possibilities for educators to consider in their learning and teaching endeavors.

Social media can be used to organize class projects, provide supplemental help, generate online discussion, administer subject-related content, post notices and reminders, and generally enhance student interaction (Gettman and Cortijo

2015). Specifically, YouTube can be used by teachers to upload videos of assessment activities, sharing educational content and how-to explainers. This will also lead to self-paced online learning. Students can be required to record their assessments, such as presentations and role play, and upload them to YouTube. Lectures can be delivered live via Facebook, and the subsequent discussion can take place right under the video via comments. This essentially creates a discussion-like online space that allows students to ask and answer questions from each other and from teachers too. Social media can also be used as a tool to monitor posts that indicate conflict or threats. Often, students complain about resources or infrastructure on the institutional social media pages or groups. If correctly monitored, the problems can be addressed in a timely manner.

Social media usage is also exponential in the tertiary education marketing domain, where institutions are using it to canvas their course offerings, attract students, and then continue interacting with them on various social media platforms. Sharing information about campus events, as well as sharing and tagging of photos, creates an informal social network that enables students to further engage in the promotional process. Prospective students use social media channels to find out about universities. The International Student Survey by Hobsons (2017) showed that 82% of international students used social media to research universities even before making an enquiry. The study also found a positive correlation between the popularity of a university's social media platforms and international student recruitment numbers.

Challenges of Social Media for Tertiary Education

A study by Moran et al. (2011) highlighted key barriers to social media usage by higher education faculty. These were lack of integrity of online submissions, privacy concerns, lack of integration with existing learning management system, steep learning curve, and lack of institutional support. Students are concerned that their personal information could be seen by their teachers (Akçayir

2017). The concerns of privacy invasion on social media, especially when teachers and students are able to see each other's profiles and access personal information, are a major challenge. Another negative effect of social media is that some students might unknowingly publish content that might harm their reputation, which might have an effect on their study too. Students who freely participate in online debates and express opinion only on social media miss out on developing public relations skills. This might have a debilitating effect on their confidence in public speaking and lead to social interaction problems.

The use of social media for learning and teaching activities often implies that academics have to deal with an assortment of complex university policies and procedures and this can often lead to confusion (Willems et al. 2016). This frequently creates tension, as academics struggle in the debate of whether to use social media for their teaching and learning activities or not. On the other hand, some teachers' conservative attitudes about the utilization and experimentation with technological innovations also contribute to the lack of social media usage (Callan and Johnston 2017). Another challenge is that some academics may not be familiar with social media and how best to use it to improve pedagogical practices. The problem only exacerbates with so many different social media platforms in existence, each with its own bells and whistles.

Social media is also seen as a distraction from learning and teaching activities, primarily because it is mostly used for entertainment-based activities. Students see social media as a social networking tool rather than as a formal teaching tool. Hence, they are reluctant to use it for formal educational activities (Gettman and Cortijo 2015). Previous research has indicated that if social media usage in academia does not contribute to academic activities, its use is associated with negative academic performance among students (Junco 2012; Stollak et al. 2011). Having continuous access to social media is also distracting. It makes students less productive, and the temptation to check their social network sites for updates might take precedence over study. The relevance of information on social media is very important. Students could spend many hours browsing social media but not practically gaining

anything, except for the loss of valuable time. It can also be argued that in many social media groups created by tertiary education institutions, the students like to stay "in touch," especially when they are studying, but the "touch" and online social connection lose context once students have graduated.

Guidelines for Social Media Usage in Tertiary Education

There are an overwhelming number of social media platforms in cyberspace, some that are for general use and some that specifically cater to the education sector. Teachers need to decide what works best for their student cohort and for themselves too. One of the key factors that influence the choice of platform is the number of people using it. Facebook tips the scales in favor of all other social media platforms, primarily because of its more than 2 billion user base. Then, there is the need to consider the type of content that needs to be shared. If there is visually compelling content, then Instagram might be useful; but apart from photo sharing, Instagram has no apparent use for content sharing and educational interaction. YouTube can be a compelling platform to share videos to a large audience who are not necessarily part of an institution's social network. Facebook can be used to share videos and class notes and encourage interaction.

Some educational institutions use dedicated social media platforms such as Ucuroo, which limits any outsider access and provides more privacy. It is also linked to institutional accounts, negating the need for creating any further accounts. However, power lies in numbers, and if more people are using Facebook, then it is a clear winner. Hence, tertiary education institutions need to find ways of incorporating it for various uses, be it advertising, marketing, promotion, or importantly for learning and teaching activities. To alleviate privacy concerns, academics can create Facebook private groups for their classes, so the groups are not visible to anyone outside the private class group, although this does create a resourcing and monitoring issue. Facebook groups can be seen as a learning management system that allows easy dissemination of educational content and interaction between its members,

and academics can be made responsible for monitoring their groups. It is necessary for teachers to guide students about the privacy settings offered by social media tools such as Facebook and YouTube. To reduce the distraction of students, social media usage in academia should focus on the dissemination of relevant information, particularly so that it aids in meeting learning outcomes and scaffolding assessments. To keep alumni involved with their alma mater, meaningful social media posts should be created to keep them engaged.

Tertiary education institutions should not assume that academic staff are necessarily comfortable with the use of social media to enhance their teaching and learning practices. Ongoing professional development of staff should be provided along with examples and case studies of instances where social media usage has proved to be a success. Social media is constantly evolving, and students and teachers alike have to keep themselves abreast with trending technologies.

For effective use of social networking sites, documented guidelines can provide clarity and practical advice to positively channel online discourse (Chugh 2012). Dedicated social media policies around learning and teaching activities should be developed as generic social media usage policies are not sufficient to deal with the intricacies of the evolving and multifaceted nature of social media. Staff's usage of social media will be better guided by detailed policies that provide advice on confidentiality and codes of conduct. A code of conduct that outlines expectations of staff when using social media platforms is a necessity, especially because staff will be conducting official work on social media. It is also recommended that staff create a separate account using their institutional email for all learning and teaching-related social media interaction. This will also enable some privacy to be maintained as students will not be able to access personal information.

Conclusion

In every tertiary educational institution, critics and advocates will continue to debate the role of social media. Nevertheless, the widespread adoption and

use of social media has the capacity to change and revolutionize education. It has the underpinnings of becoming the classroom of the future. Leveraging social media to improve the educational process is imperative. Tertiary education institutions should not lag behind and must progressively consider incorporating social media into teaching and learning activities.

The value of social media usage in tertiary education not only lies in making announcements, marketing, and advertising but also for learning and teaching purposes. Social media can be implemented for pedagogical activities. It has the potential to improve academic performance, enhance interaction and collaboration, increase communication between teachers and peers, provide convenient access to teaching and learning content, and build relationships. However, social media may not necessarily work well for all teaching and learning scenarios, as a diverse range of pedagogical dynamics need to be considered. Hence, it should currently only be used to complement traditional practices over total replacement.

In implementing social media in tertiary education, if a bottom-up approach is not adopted by teachers, then a top-down approach may work, especially because the dominance of social media cannot be ignored. In doing so, the importance of institutional support to make social media implementation smoother should not be overlooked. Specialist teaching and learning social media champions should be identified. These people can play a pivotal role in promoting best practices while advocating and guiding other academic staff on incorporating social media in their subjects.

Just because social media is abuzz everywhere does not necessarily imply that it will work for tertiary education in the same way that it works in other domains. Staff need to be aware of the benefits, the challenges, and the opportunities that social media can bestow upon tertiary education institutions. This entry briefly outlined some of the key issues around social media usage in tertiary education institutions, in particular by highlighting some guidelines that could help in the adoption and adaptation of social media. The major contribution of this entry is to provide a tertiary information source for academics, administrators, and managers to enable them to conclusively understand some of

the main considerations that will influence the adoption and use of social media in tertiary education.

The blurred boundary between the formal and informal use of social media will always remain an issue of consideration, not just in academia but in varied other settings too. In spite of the drawbacks and challenges, social media will continue to evolve, becoming better integrated with learning management systems and changing the educational landscape.

Cross-References

- [Collaboration and Social Networking](#)
- [Social Media and Networks as Digital Instruction and Learning Platforms](#)
- [Social Networking in Higher Education](#)
- [Using Social Media to Promote Academic Functioning](#)
- [Wikis as a Collaboration Tool](#)

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Social Media in Shadow Education in China, An Introduction

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Introduction

Over the course of almost 40 years, distance learning has transitioned from the periphery into mainstream education (Zawacki-Richter and Naidu 2016). As a branch of distance learning, social media has recently begun to attract considerable scholarly attention. Social media, also known as Web 2.0, is an umbrella term used to refer to Internet platforms, tools, or apps that support netizens to communicate and collaborate on mobile devices. Examples of social media include Facebook, YouTube, Youku, Twitter, Weibo, WeChat, and even different massive open online course (MOOC) platforms.

Social Media in Education

At the practical level, social media in education has been found to be useful as a method of teaching and learning. Due to its connection with the ubiquitous Internet, social media has the ability to connect teachers and students both inside and outside of classrooms, increasing the opportunities for peer support and collaboration, and teacher–student communication (Ding and Stapleton 2015; Li 2016; Al-rahmi et al. 2014). Social media is also claimed to be efficacious in increasing students' access to knowledge

(Li 2016), creating personal learning environments (Dabbagh and Kitsantas 2012), and facilitating informal learning (Dede 2016).

From a more transformative perspective, social media is also claimed to promote democracy and equity, as it exposes people to more educational resources at lower costs (Reshef 2016; Bramble and Lu 2016; Warschauer 2016). In China, the transformative properties of social media in the context of educating children from low-income families and school dropouts have been found to be particularly useful, as a mobile phone is a relatively cheap device for a low-income family enabling them to connect to the Internet (Wang 2016; Miller et al. 2016).

Social Media Surge in China

Social media is one of the most dynamic and innovative industries in China (Hu et al. 2017). Since the concept of MOOCs was imported to China in 2011, China has developed one of the largest MOOC user bases in the world, following the USA, Brazil, and India (Trehan et al. 2017), although only a few of the more prestigious universities are involved in developing MOOCs (Zhou 2016). The statistics of the population of MOOCs users were excluding users from other social media platforms.

According to a report on the Chinese education industry published by Deloitte in 2016, many traditional offline education schools have begun to offer online education (Deloitte 2016, May). An interesting phenomenon in China is that many non-education-related Internet companies have entered the commercial online education industry. Adkins (2015, March, p. 6) used an analogy to describe this situation: “imagine if Google, Google’s YouTube, Yahoo, eBay, Facebook, Microsoft, Microsoft’s Skype, Gameloft, Twitter, IBM, Amazon, and eHarmony all entered the commercial learning technology market at the same time.”

However, there has been little discussion in the literature concerning how social media has been integrated with shadow education in China. Shadow education is a key arena in

which Chinese parents compete for extra training for their children. Such competition centers upon China's National College Entrance Examination, the Gaokao, and the Senior High School Entrance Examination, the Zhongkao, where the stakes are high as students compete for admission to colleges and high schools. Also, the unequal distribution of educational resources across different regions and schools has further increased competition between parents and pushed them to use "shadow education" to maintain or gain competitive advantages in these important examinations (Yu and Ding 2011; Zhang 2011).

Shadow Education in China

Shadow education, which is also known as private supplementary tutoring, is fee-paid tuition outside of formal schooling hours (Zhang and Bray 2016). It "shadows" mainstream education offerings, mimicking the curriculum taught in schools. Bray (2009) has defined the common form of private supplementary tutoring as having three characteristics: privacy, supplementary, and academic. Privacy means that tutoring must be provided on a paying basis. Supplementary refers to the fact that tutoring is in similar subjects to those in formal schools, but delivered outside of school hours to supplement mainstream schooling. Finally, academic implies that tutees should be examined in regular schools. In the Chinese context, the definition is even broader. In a study by Liu and Bray (2017), academic and non-academic tutoring are included as examples of investment by families to improve students' performance in mainstream school examinations. A study by Wright et al. (2018) expands the definition even further, to include private tutoring for students at international schools in China offering the International Baccalaureate curriculum. However, the majority of research conducted in China focuses on shadow education as a parallel system to Chinese mainstream education at primary and secondary level (e.g., Kwok 2010; Zhang 2014; Zhang and Bray 2017).

With the increasing prosperity and competition within Chinese society in recent years,

shadow education in China has developed rapidly (Zhang and Bray 2015). However, this has also raised concerns regarding its negative impact on increasing social inequality (Zhang and Bray 2016), as parents who can afford supplementary education are those from more advantaged financial backgrounds and with more abundant educational resources. Previous studies indicate that in some schools over half of students receive private tutoring over and above school hours; this percentage increases to approximately three quarters in some urban areas (e.g., Zhang 2011; Zhang and Bray 2017). In China, the urban-rural division continues to be a cause of significant inequality in economic and education resources (Yang et al. 2014); it is hoped that the integration of social media will reduce this inequality.

Modes of Social Media Use in Shadow Education in China

Generally speaking, recorded video education, "1&M" (one teacher teaching many students), live education, "1&1" (one teacher teaching one student) live education, and homework helpers are the modes currently used in social media-integrated shadow education in China (China Industrial Information 2016). Recorded video education is the most traditional mode, and requires essential website functions for uploading, video viewing, and commenting. A large number of different schools, including the New Oriental School, accept this mode due to its low cost and "once-for-all" efficiency. Schools can record lessons and upload videos onto social media platforms, such as Youku, similar to YouTube, enabling students in different locations to watch online, at any time and from any place.

The 1&M mode is a livestream mode of teaching, where a teacher can simultaneously talk to multiple students in a chat room. Some large education corporations, such as Koolearn, Xueersi, and Global IELTS, have been early adopters of 1&M, building up online chat rooms and pitching lessons online. YY, a livestream

social media app, recently opened the floor for small business owners and self-employed teachers to deliver livestream classes. This increased the choices available to both students and teachers, breaking down barriers within and between cities, and even countries.

1&1 online education has also reached a prosperous stage, and since 2016, especially for English language learning, which in 2018 has become a favored area attracting investment from various financial organizations. Social media apps such as VIP KIDS and 51talk stand out as typical 1&1 mode applications, which invite native speaker teachers to teach Chinese students oral English via live chat. The 1&1 mode is beneficial for families who otherwise would not have access to native-speaker teachers for their children.

Recently, the theme of shadow education has been extended from personal teaching to homework assistance. Homework-helper social media platforms such as Zuoyebang and Little Ape are new brands exploring the concept of shadow education. These platforms also use livestream and live chat to connect teachers and students located thousands of miles away, to supervise and to give guidance to students who have difficulties completing homework. The user-friendly functionality attracts a certain group of clients, in particular those parents who are not able to provide academic help to their children.

Conclusion

The surge in social media usage in China has fueled its integration into shadow education, as businesses have begun to invent and adapt different apps and platforms to launch different modes of online classes, for example recorded video education, 1&M, 1&1 live education, and homework helpers. In this way, social media has increased the accessibility of shadow education resources for students, particularly those in rural areas with lower income and relatively fewer resources than their urban peers.

Cross-References

► Social Media for Tertiary Education

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Social Networking

- [Social Networking in Higher Education](#)
- [WhatsApp for Electronic Feedback and Assessment](#)

Social Networking and Education Model (SNEM)

- [Social Networking in Higher Education](#)

Social Networking in Higher Education

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Synonyms

[Personal skills](#); [Professional skills](#); [Social networking](#); [Social networking and education model \(SNEM\)](#); [Wiki](#)

Introduction

Social networking (SN) has become one of the crucial technologies enabling several generations – baby boomers, X, Y, Z, and Alpha – to connect, communicate, and collaborate among their peers locally and globally. Several sectors, such as education, commercial business, entertainment, government, and others, are now using this technology to communicate and collaborate with their stakeholders, employees, and students. Education systems locally and globally have for many years been observing students' and businesses' needs in order to appraise and improve curricula so as to advance students' skills and meet business needs by using up-to-date technology in their teaching and learning practices. This technology can encourage and improve human endeavors to

acquire the students' academic skills required for study and the workforce. In the higher education sector, academics have begun to acknowledge and meet the needs of the new generations, Y and Z. These generations depend on the new technology in their everyday lives, especially for the purposes of study and work. Therefore, to encourage and motivate students, academics have begun to include some assessments and activities in their courses which involve the use of social networking tools such as Wikis, blogs, Facebook, and podcasts. This technology allows students to create and develop collaborative communication with other students and establish a niche community with similar interests and knowledge in the education domain as well as in business. As mentioned above, social networking has been adopted by the higher education sector as a means of improving the process of knowledge acquisition and ensuring social interaction among students and between students and lecturers.

Furthermore, this technology is not limited to the higher education sector, as both public and private sector organizations are now using it to contact and communicate with customers and to interact and collaborate with their stakeholders since the interface design has been developed with intellectual features to encourage user interaction. Moreover, SN tools have the advantage of being able to disseminate cutting-edge knowledge, foster collaboration, establish intercrossing relationships, improve communication skills, and facilitate the acquisition of new acquaintances. Moreover, it is an environmentally friendly mode of communication. However, SN can also pose several risks associated with cognitive, social, and physical development and security issues. Therefore, when institutions are planning to implement this technology in any field including the higher education sector, specific guidelines and models should be used to increase the advantages to students and stakeholders as a result of interaction, collaboration, communication, and connection; moreover, by following these guidelines and models, the risks, i.e., cognitive development, social development, physical development, and security, can be mitigated or even eliminated.

In this entry, the author will examine the meaning of social networking in general but will also examine its meaning in the context of higher education, discuss the social networking and education and social networking and education model (SNEM), and provide an example of social networking (i.e., Wiki). The entry also considers possible future research directions that can give further insights into social networking, especially in the higher education sector. This entry is organized as follows: introduction, social networking, social networking and education, social networking and personal and professional skills, social networking benefits and risks, social networking and education model (SNEM), implementing SNEM, and conclusion.

Social Networking

The use of technology in higher education is intended to improve collaboration, communication, cooperation, and connection among students and between students and lecturers. Currently, students in many higher education institutions are using various technologies such as Wikis, blogs, Twitter, Facebook, and Blackboard for tasks and assessments. World Wide Web (WWW) originated from the word web, and the web plays an important role in obtaining and disseminating information with the assistance of the technology. Social networking applications are based on variations of web technology, namely, Web 1.0, Web 2.0, Web 3.0, Web 4.0, and Web 5.0. Web technology began with read-only web and developed into read and write, semantic web, concurrent read and write web, and then tracking users' behaviors receptively (Benito-Osorio et al. 2013; Franklin and Van Harmelen 2007; O'Reilly 2007; Jiang 2014; Miranda et al. 2014; Powell et al. 2012; Spivack n.d.).

Several studies (Funk et al. 2013; Hazari and North 2009; Mahruf et al. 2012; Morgan 2009; Rao 2005) have confirmed that communication technologies, including the social networking platforms, play a major role in higher education in increasing participation and interaction among

students and between students and lecturers. It has been found that this type of communication has the potential to improve students' self-esteem and confidence, particularly through presentation and debate activities.

The web technologies serve as a platform for users and business to interact and communicate with other parties globally and locally. The Web 2.0 applications facilitate social interaction and access to information regardless of distance and time. The technology service is flexible, well-organized, actual, and user-friendly so as to meet users' and businesses' wishes and requirements. Figure 1 presents some of the social network applications, namely, Wikis, blogs, Mashups, Tags, and podcasts (Augar et al. 2004; Biasutti and El-Deghaidy 2012, 2015; Godwin-Jones 2003; Gokcearslan and Ozcan 2011; Heng and Marimuthu 2012; Zein 2014).

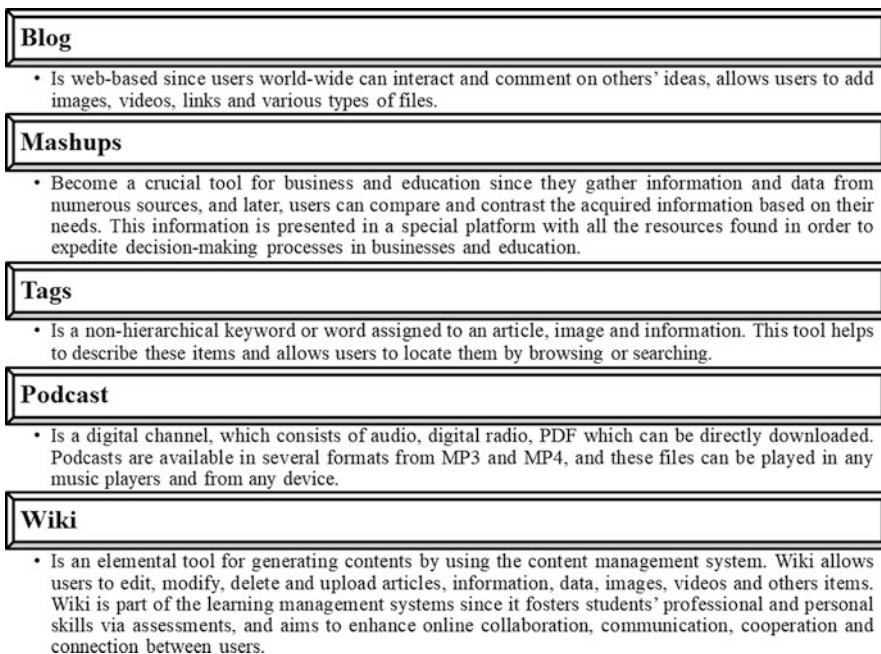
Social Networking and Education

Since last century, WWW has become the common information media utilized by

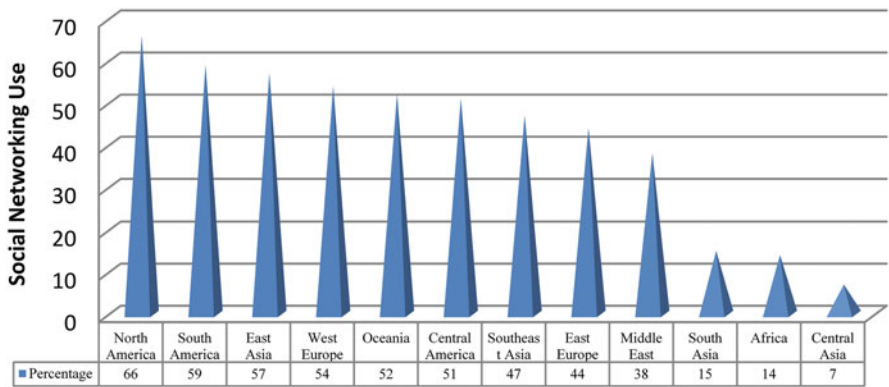
several generations to communicate, collaborate, connect, cooperate, and exchange information, knowledge, and data between students, organizations, and stakeholders locally and globally.

According to the Statista (2017) website, North America has the largest share of social networking usage in the world, followed by South America, East Asia, West Europe, Oceania, Central America, Southeast Asia, Eastern Europe, the Middle East, South Asia, Africa, and, finally, Central Asia. Figure 2 shows that this tool is used by more than three million users globally for sharing knowledge, data, and information in various sectors including the education sector. This development of social networking and the variety of user languages on the web has brought several advantages to both the business and education sectors. However, this tool also presents some risks to users.

Several studies (Cummings 2013; McCarroll and Curran 2013; Issa et al. 2014b; Özmen and Atıcı 2014; Duygu and Zahide 2015; Feinstein et al. 2015; Fox and Moreland 2015; Peldon and Issa 2015; Al-Oqily and Alkhatib 2016;



Social Networking in Higher Education, Fig. 1 Web 2.0 applications. (Prepared by Tomayess Issa)



Social Networking in Higher Education, Fig. 2 Global social network penetration rate by region as of January 2017. (Prepared by Tomayess Issa (Statista 2017))

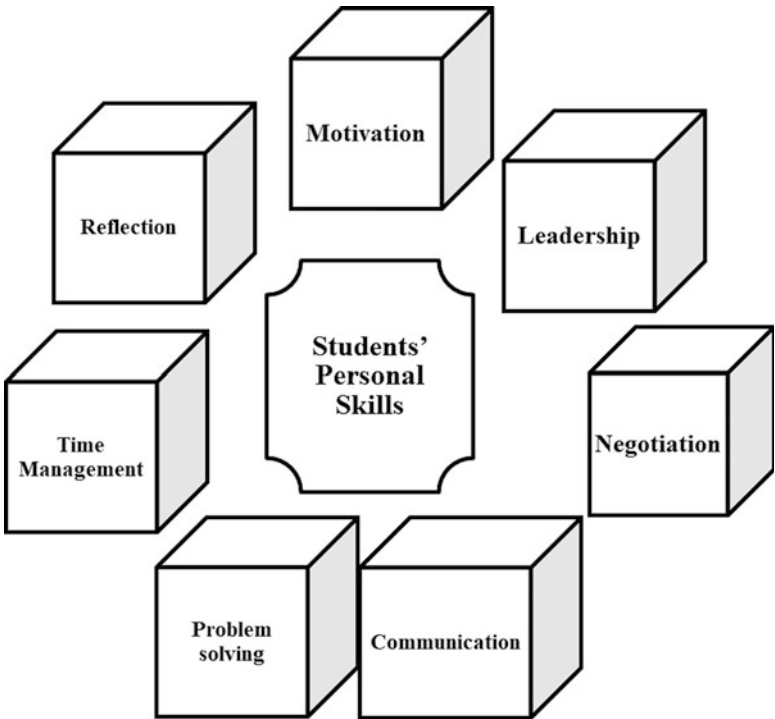
Alqahtani 2016; Goktalay and Ozdilek 2016; Issa 2016; Turel and Bechara 2017; Vernon et al. 2017; Shi et al. 2018) indicate that SN is an online application that allows users to generate accounts for their profile and to add, edit, and delete their contacts and to meet and interact with real colleagues locally and globally. As mentioned previously, SN is intended to simplify the exchange and discussion of ideas and encourage collaborative communication and connection among users from various sectors including businesses and education. Social networking enables users to post, publish, and write articles or comments in sites such as Facebook and Google (Christoffersen et al. 2012). Currently, in the higher education sector, many academics integrate SN tools in their assessments and activities; these tools include Wikis, blogs, and discussion boards which are available in the LMS (learning management systems). The integration of these tools in the assessments and academic tasks will assist both students and lecturers to develop more interaction and communication, while students’ academic and students’ personal skills will improve as a result of undertaking tasks independently or in a team (Van Deursen et al. 2011; Bednarz 2014; Benson et al. 2014; Isaias and Issa 2014; Issa et al. 2014a; Tambe 2014; Chu et al. 2017; Novakovich et al. 2017; Ruge and McCormack 2017).

Social Networking and Personal and Professional Skills

The use of SN in higher education has transformed teaching and learning methods, since students become more independent learners by using various media such as Wiki, blog, and discussion board. These tools are user-friendly, and students can submit individual and team work to the lecturer for assessment based on rubric. These tools have been introduced in the higher education sector in order to improve both academic (reading and writing, research, information and technology, critical thinking, decisionmaking, digital oral presentation, and drawing (i.e., concept maps)) and students’ personal skills (i.e., motivation, leadership, negotiation, communication, problem-solving, time management, and reflection). These tools facilitate and encourage greater interaction, participation, debate, and discussion among students and lecturers when engaging in various assessment tasks and class activities (Issa 2014, p. 13). Moreover, several studies (British Medical Association 2004; Sancho-Thomas et al. 2009; Chu et al. 2017; Novakovich et al. 2017; Ruge and McCormack 2017; Taraghi et al. 2009) have confirmed that the use of technology (especially SN) will encourage students to become independent learners and will improve their academic and students’ personal skills, particularly since it enables them to regularly access their teachers’ feedback (see Figs. 3 and 4).

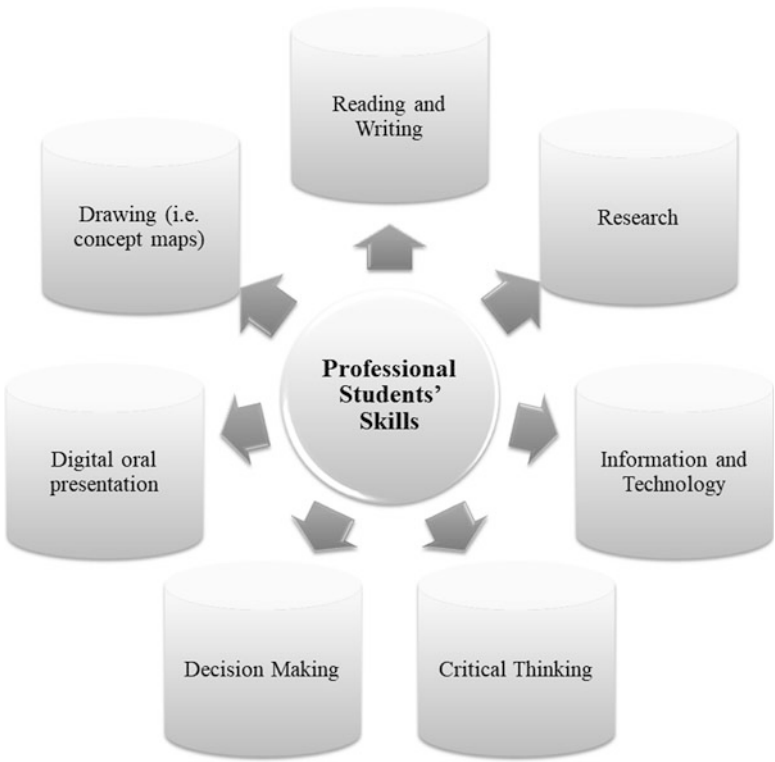
Social Networking in Higher Education,

Fig. 3 Students' personal skills (PK). (Prepared by Tomayess Issa)



Social Networking in Higher Education,

Fig. 4 Students' Professional Skills (PrK). (Prepared by Tomayess Issa)



Social Networking Benefits and Risks

On the other hand, to ensure a smooth transition from traditional teaching practices to e-learning teaching, lecturers will need to play a key role in the effective delivery of teaching, since the lecturer is a facilitator of teaching and learning, not the technology (Singh et al. 2005). Wilson (2001) suggests that three characteristics of the lecturer will control the degree of learning that occurs: attitude toward technology, teaching style, and the control of technology. On the other hand, the use of SN in the higher education assessments and activities will bring new benefits for students, namely, exposure to cutting-edge knowledge, the opportunity for collaboration and intercrossing relationships, enhanced communication skills, acquisition of new acquaintances, and an awareness of an environment-friendly means of communication. However, SN poses several risks associated with cognitive, social, and physical development and security (see Figs. 5 and 6).

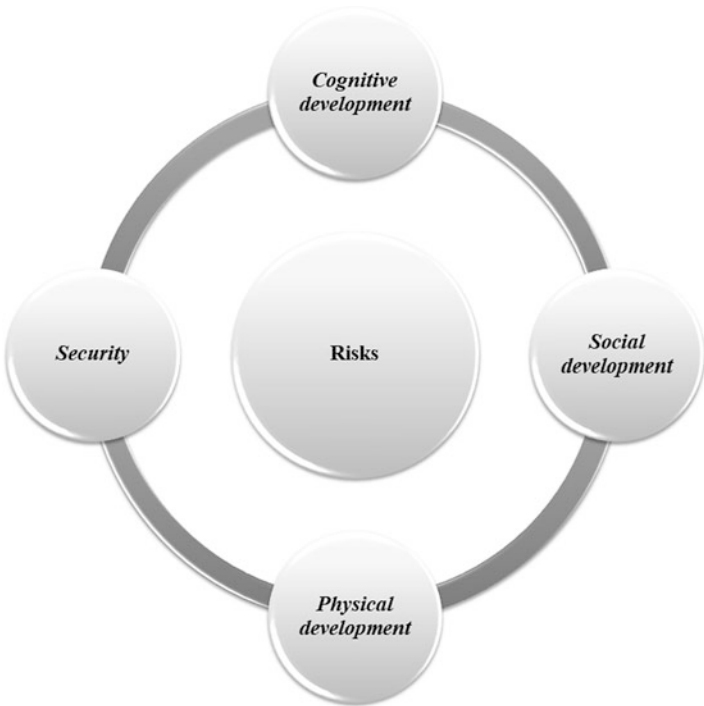
Social Networking in Higher Education,
Fig. 5 Social networking opportunities in higher education. (Prepared by Tomayess Issa)



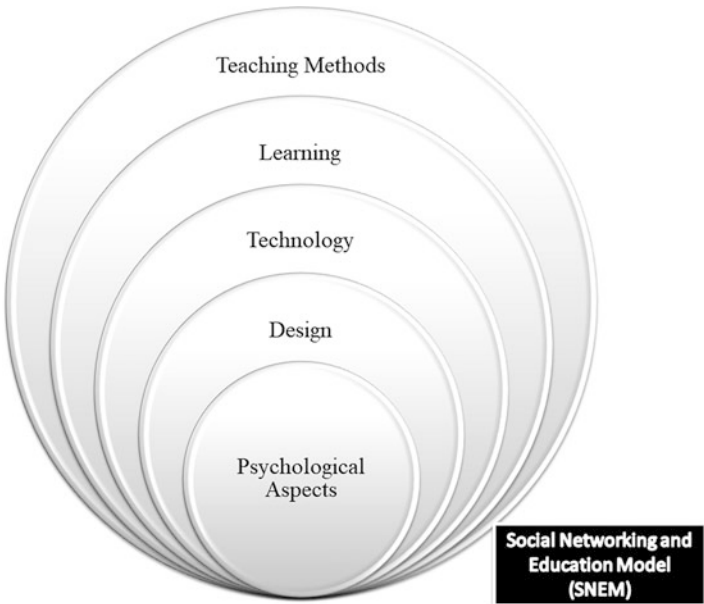
Social Networking and Education Model (SNEM)

Consequently, in order to implement SN efficiently, especially in higher education, the social networking and education model (SNEM) should be used (Issa et al. 2016). SNEM was developed and created based on an intensive study of 15 countries comprising both developed and developing countries. The study confirmed that using SN in higher education developed students’ academic skills, expanded their knowledge of local and global issues, and assisted students to study and work independently; moreover, the use of SN makes students more sustainable. However, SN can also cause anxiety, loss of interest in everyday activities, health concerns, and security fears. It may prevent students from undertaking their regular activities and, finally, may hinder the development of literacy and other fundamental skills. The SNEM contains the following elements: teaching methods, learning, technology design,

Social Networking in Higher Education,
Fig. 6 Social networking risks in higher education.
(Prepared by Tomayess Issa)



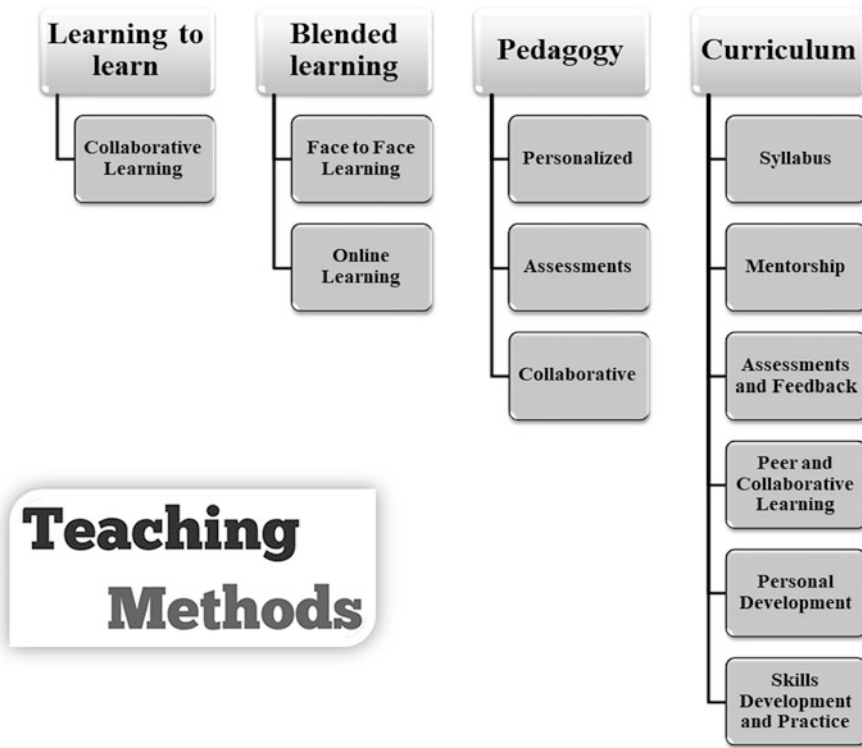
Social Networking in Higher Education,
Fig. 7 SNEM. (Prepared by Tomayess Issa)



and psychological aspects. Each of these contains several sub-elements to ensure the successful adoption of SN by the higher education sector.

Teaching methods consist of four elements: learning to learn, blended learning, pedagogy,

and curriculum (Murphy et al. 2004; Smith et al. 2009; Thrun 1996; Hughes-Wiener 1986; Oliver and Trigwell 2005; Driscoll 2002; Mockler and Groundwater-Smith 2015; Lalonde and Castro 2015). Figure 7 shows the sub-factors of each of



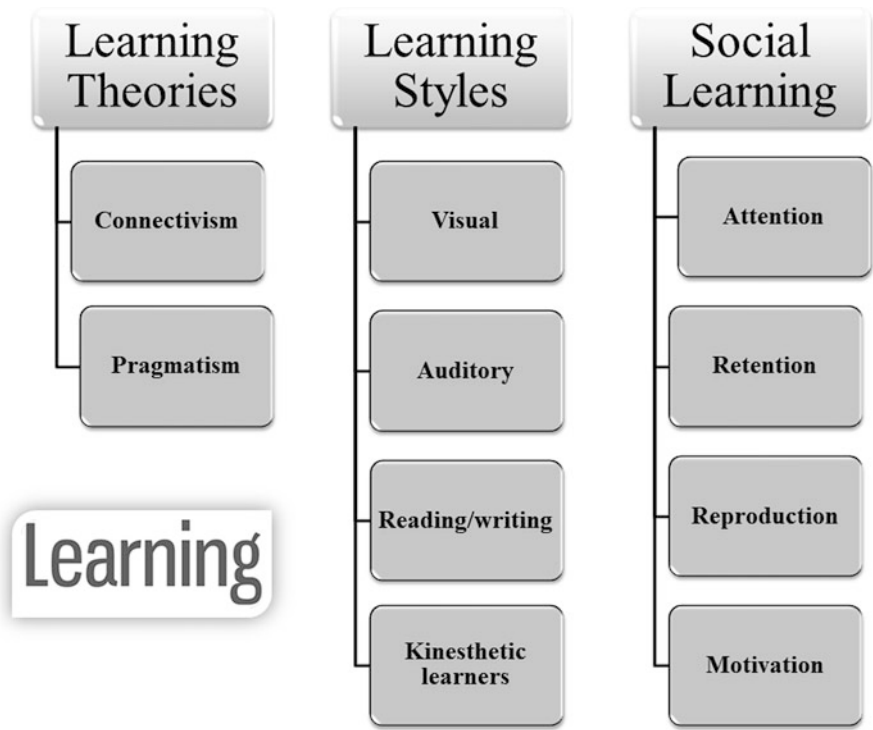
Social Networking in Higher Education, Fig. 8 Teaching methods. (Prepared by Tomayess Issa)

these. Learning to learn involves a set of principles and skills that will assist students to learn more effectively and so become learners for life. Blended learning combines face-to-face learning and online learning; these modes are essential in teaching and learning as a means of delivering the materials and information to students. Pedagogy and curriculum are related to teaching principles, professional practice, leading, guiding, and methods of teaching; on the other hand, curriculum relates to assessment tasks and activities which students are required to complete successfully in order to achieve specific educational outcomes.

The learning factor emerges from learning theories, in particular, learning styles and social learning. Learning theories are divided into two categories: connectivism and pragmatism (see Fig. 8). Connectivism is the theory for the digital age; it states simply that knowledge, data, and information are disseminated via a network of connections; therefore, the learning and teaching

process involves the construction and traversal of those networks, especially by using the latest technology (Siemens 2005; Duke et al. 2013). However, the pragmatism learning theory involves mainly hands-on problem-solving; teamwork, experimentation and projects, and subsequently the outcomes will be used for decisionmaking (Kivinen and Ristelä 2003; Wallace and Brooks 2015).

The learning style is based on Neil Fleming's VARK (1988) (Felder and Silverman 1988; Murphy et al. 2004; Fleming 1995): visual, auditory, read/write, and kinesthetic learning modes (see Fig. 9). Visual learners prefer to use concept maps, drawings, graphs, and flow charts instead of texts and audio material. This type of learner relies on visual cues and can better understand the information if it is presented graphically. These visual representations are tools that will help these learners to organize their ideas and understand the concepts being presented. Auditory learners prefer to listen and speak instead of taking notes from



Social Networking in Higher Education, Fig. 9 Learning. (Prepared by Tomayess Issa)

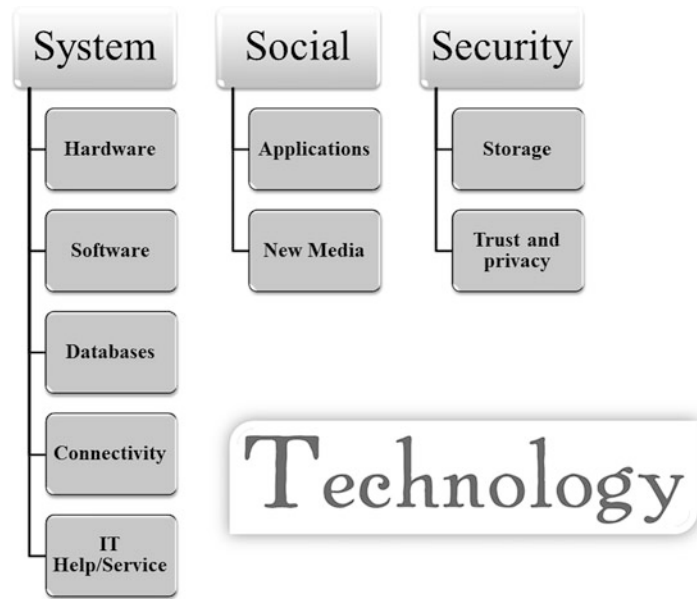
the lecturer. This group has the ability to discuss and debate with his/her classmates and lecturers as a means of understanding the concepts of the unit being studied. This group prefers to use the latest auditory technology such as MP3/MP4 audio which allows them to pause, forward, and rewind, especially those sections that they have difficulty understanding. The read/write learners prefer text, notes, and papers as a means of understanding concepts. These types of learners are able to interpret abstract perceptions and convey them through arguments and essays. Finally, kinesthetic learners prefer to learn through experience and practice; this means that they feel and live the experience in order to learn.

Social learning involves attention, retention, reproduction, and motivation (Bandura 1977; Cheung et al. 2015). Attention: learners need to pay attention in order to obtain the knowledge presented in the unit of study; any interruption or distraction will affect the learning process. Retention: this concept mainly concerns the process of remembering the information that the

student has obtained from notes, images, models, and other materials and resources. Reproduction: students are required to reproduce the information which they learned during the class, which in turn reflects their level of attention. This behavior will ensure that if students are receptive to information, their skills and observational learning will improve. Finally, students should have the motivation to repeat their performance at the same (hopefully high) standard and be aware that appropriate performance will be given positive recognition, and, conversely, substandard performance will have negative consequences.

The technology factor comprises three sub-factors, namely, system, social, and security (see Fig. 10). These sub-factors are essential for SNEM to ensure that social networking is effective and aligned with students' needs, especially in terms of the security of data storage and the user's private information. The system factor relates to the practical implementation of social networking in higher education; universities are required to provide hardware, software,

Social Networking in Higher Education,
Fig. 10 Technology.
(Prepared by Tomayess Issa)



Social Networking in Higher Education,
Fig. 11 Design. (Prepared by Tomayess Issa)



databases, Internet connectivity, and troubleshooting (support and help) for students and lecturers. The final sub-factor is social. For SN implementation to be successful, students need the latest applications and media such as Blackboard, Moodle, and other facilities.

In order to implement social networking without creating user frustration, design plays an essential role in this model, especially in terms of interface: usability, human-computer interaction (HCI), and navigation (see Fig. 11). Attention to these aspects of SN is vital since usability means that the interface is efficient, effective, safe, easy to learn, easy to remember, easy to use and to evaluate, practical, and visible and provides a satisfactory experience. The principles of HCI

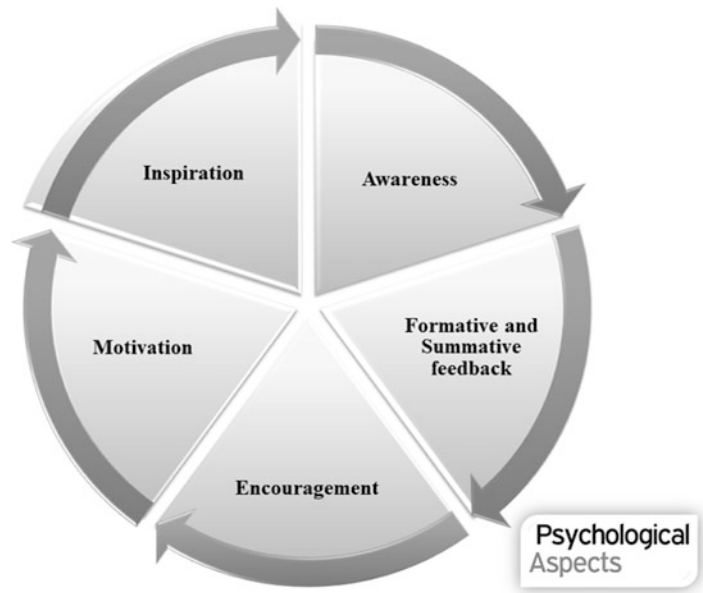
are intended to ensure that the interface is practical and visually attractive in relation to text, style, fonts, layout, graphics, and color (Issa and Isaias 2014). The navigation sub-factor aims to establish communication between the interface and navigation in the hypermedia application (Issa 2008).

The final factor in SNEM is the psychological aspect (see Fig. 12); this factor will assist teachers to understand students' cognitive and behavioral attitudes toward the use of this technology in the learning and teaching process (Safuanov 2004; Lalonde and Castro 2015; Watson 1963; Monks and Kawwa 1971).

Furthermore, this factor will assist students to meet their study needs and requirements, since teachers using the technology play a major role

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Fig. 12 Psychological aspects. (Prepared Tomayess Issa)



especially in terms of activities and assessments. According to Issa et al. (2014c, p. 30), “The constructive feedback is intended to ascertain whether students are on the right track, and to allow students to learn from their mistakes and prevent future repetitions of the same errors. Furthermore, the adoption of this approach in postgraduate and undergraduate units will improve students’ confidence and motivate them to complete the assessment tasks on time, and most importantly, align with the unit objectives and aims.” The formative feedback is intended to raise students’ awareness and encourage, motivate, and inspire them during the learning process, fostering their independent learning and improving their students’ academic skills and students’ personal skills by using the technology and, in particular, accessing their teachers’ regular feedback. Furthermore, both formative and summative feedback will encourage students to engage with the unit and will provide an exciting, memorable, and motivating experience. Motivation is the factor that assists users to move toward a goal or aim, while the purpose of encouragement is to give courage, hope, and increased confidence to users to strive to achieve their aims. The idea of awareness is to have knowledge or judgment of something, while inspiration is a

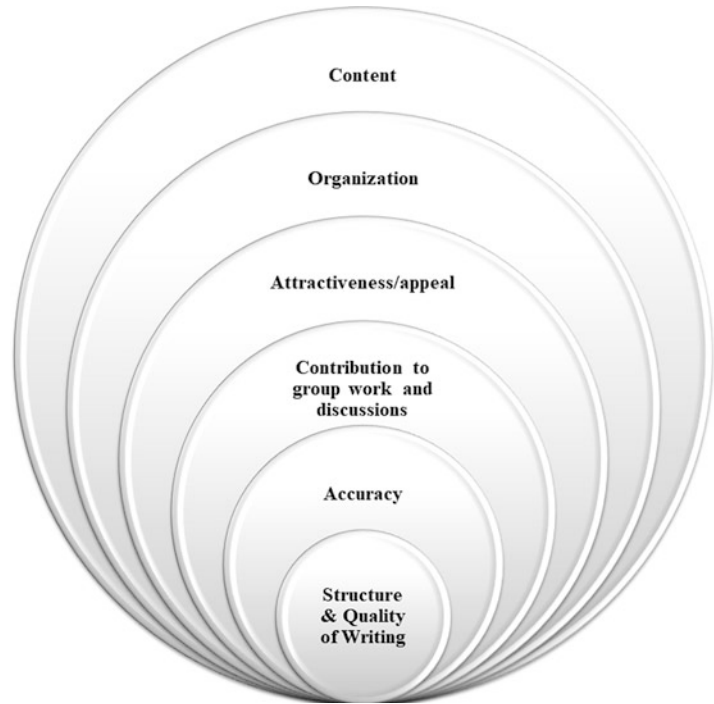
process that takes place when a user sees or hears something that causes him/her to develop and generate new ideas (Business dictionary 2015; The Encouragement Foundation 2015; Psychology Dictionary 2015; What is How to Info 2015).

Implementing SNEM

The SNEM was implemented in one of the author’s postgraduate units by using the Wiki (WK) tool which is integrated in the Blackboard facility. The use of Wiki as a teaching tool improved the students’ communication skills (writing, interpersonal interaction, and presenting), as well as their critical and creative thinking (problem-solving and decisionmaking), and their technology and information literacy. Additionally, the incorporation of Wiki tool in teaching and learning practice, especially in the author’s teaching unit improved the quality of students’ work, their productivity, and self-confidence. Students added, modified, and deleted information and data by means of the Wiki tool, and this encouraged and developed their independent learning process during both individual and team activities.

Social Networking in Higher Education,

Fig. 13 Wiki rubric.
(Prepared by Tomayess Issa)



Students completed several challenging, practical exercises which required them to analyze and evaluate real case studies and to then upload the results to the Wiki to be evaluated by the lecturer and student peers. Subsequently, individuals or teams presented the results using PowerPoint slides or concept maps.

The Wiki submission was graded according to a pre-established rubric which contained the following assessment criteria (see Fig. 13): content (i.e., topic(s) is/are covered in detail with excellent examples; knowledge of subject matter is outstanding), organization (well-presented and organized, using headings or bulleted list to group related material), attractiveness/appeal (to enhance the Wiki presentation; student uses excellent choice of font, color, graphics, effects, etc.), contribution to group work and discussions (student contributes to and develops the class Wiki, by providing her/his opinion regarding her/his colleague's Wiki contribution), accuracy (student's observations and perspective were presented, explained, and demonstrated well), and structure and quality of writing (well structured (e.g., paragraphing; sentence structure; spacing;

spelling; proofreading; no HTML errors in Wiki, i.e., broken links and missing images; above-average standard of expression and presentation; excellent overall expression and presentation; accurate acknowledgment of sources)).

Students were very pleased with the use of the Wiki tool in the teaching and learning process, and their feedback was gratifying:

I was impressed by the way lecturer teaches the unit. It involves discussion as well as Wikis helps us to be self-involved as we come to know the current happenings around the globe (Student 1).

Adding content in a Wiki also has a more collaborative feel to it and feels less restrained so in my mind it allows for a more free flowing conversation to occur on the subject at hand (Student 2).

It motivates me to share my ideas using Wiki tool, let me access other updates, observe their writings and learn writing skills from them (Student 3).

I should say that all the skill developments method has been covered in this unite such as group assessments, group activities, investigation of journals, report writing, video presentations, strategy developments methods and the Wiki exercises. These skilled developments methods helped me to improve my professional and personal skills including the writing skills, thinking skills, speaking skills, reading skills and listening skills, time

management skills, flexibility skills and planning skills, determination, evaluation techniques and communication skills. Before starting this unit I must say that I am a little bit shy person, and fear to present my ideas and talk to others. Now I feel that I can talk with others without any hesitation and can present my ideas to others (Student 4).

By writing journals and WIKIs, I was able to improve my writing and research skills. Research took more time than expected but in the end, it was easy to filter the data and get the right information. It was sometimes challenging to present my ideas in writing but now I am comfortable and confident to write and explain to someone (Student 5).

With the individual Wiki exercises, I was able to improve expressing my ideas since most of the tasks required us to share our perspectives on different subject areas (Student 6).

Each lecture discussed a new problem and possible solution, the delivery method of these concepts including the videos, Wikis, slides, graphic contents were quite helpful in understanding the emerging problems of the new world and realizing the role that we –students and academics can play in addressing these issues (Student 7).

The Wiki exercises allow students to discuss and exchange views on new and interesting topics. This new form of teaching provides an open channel for students to communicate views and solutions to tackle the various cases posted (Student 8).

I have learnt how to use Wiki tool which is I think the best way to give our ideas and thoughts. In fact, I consider Wiki is one of the amazing things to share information with students and teacher as well (Student 9).

Group activities in the class have increased my communication skills as the students are from different communities and we have gained lots of knowledge from each other and a shared number of new ideas with each other regarding green IT and sustainability to do Wiki assessments. Also, we came to know up to what extent the different countries (developing and developed) are worried about this major issue and what they are doing at present to reduce and mitigate this big problem and save our mother earth for our future generation as there is no planet B to go after. Teamwork teaches us the corporation and sharing (Student 10).

Cutting edge knowledge

- New information and knowledge
- Up-to-date information
- Awareness
- Facts/aspects of the past

Collaboration

- Communicate with Peer
Frequently/different universities and communities
- Collaborate with Peer Frequently

Inter-crossing relationships

- Intercrossing relationship with my peers
- Study independently
- Overcome study stress
- Complete my study quickly
- Understand and solve study problem easily
- Scrutinize my research study easily

Communication skills

- Develop Personal and communication skills
- Develop professional attitude toward study and work
- Concentration

Be environment-friendly

- Sustainable person
- Reliable and scalable services
- Greener
- Reduce carbon footprint in my activities

Acquire new acquaintances

- Acquire new acquaintances (Work, Friendship, Romance)
- Do what I want, say whatever I want, and be whoever I want

Based on the above feedback, the Wiki tool has become an interesting and effective means for students to engage, collaborate, communicate, connect, and cooperate with their colleagues and lecturer to exchange information, knowledge, data, images, videos, and others. Furthermore, via this tool, students confirmed that their students’ personal skills and academic skills had improved. These included skills in communication, reading, writing, problem-solving, and decisionmaking, as the Wiki provides an open channel through which students can engage and exchange ideas and opinions regarding the Wiki activities. Students confirmed that the use of the Wiki tool in a postgraduate unit assisted them to understand the other students’ perspectives from a different point of view, as Wiki contributions are available to all students and lecturer, and students can view their colleagues work and learn from new information and knowledge regarding the same activities.

Furthermore, using Wiki in the activities will allow students to share information and interaction among students and lecturer and encourage the teamwork among students. By using Wiki for their tasks, students were able to better understand

the unit materials, as they were able to search and research information regarding the Wiki activities, most of which were related to the unit materials. This type of exercise will motivate students to engage in their teaching and learning activities with more enthusiasm. Lastly, learning through Wiki is different and unique as the student becomes more excited and motivated to complete the unit successfully.

Put concisely, social networking in higher education has become an essential and useful tool enabling students to obtain the necessary and cutting-edge knowledge offered by the unit via the activities. Moreover, it improves their academic and students’ personal skills and encourages greater collaboration between students and their teachers. The introduction of Wiki as a teaching tool in a postgraduate unit achieved various benefits in terms of cutting-edge knowledge, collaboration, intercrossing relationships, and communication skills (see Fig. 14).

On the other hand, using this tool in the correct way will minimize the SN risks associated with cognitive, social, and physical development and security (see Fig. 15). By completing the Wiki

Cognitive development	Prevents me from Concentrating on writing and reading skills
	Prevents me from the fundamental knowledge and skills
	Scatters my attention
	Decreased my grammar, proofreading, and deep thinking skills
	Distraction
Social development	Prevents me from participation in social activities
	Prevents me from completing my work/study on time
	Sick and unhealthy
	Bores, stress, depress, lonely, lazy, addict, gambler
	Insecure
Physical development	Receive an immoral image and information from unscrupulous people
	Prevents me from having face to face contact with family and friends
	No physical activities
	No shopping in stores
	No watching television
	No reading newspapers
Security	No talking on the phone/mobile
	Prevents me from completing my work and study on time
	Privacy; security and intellectual property concerns

Social Networking in Higher Education, Fig. 15 SN risks. (Prepared by Tomayess Issa)

activities (individual and teamwork) in the post-graduate unit, students reduced and diminished the cognitive and social development which is considered a good progress for both the students and the lecturers.

Conclusion

This entry introduced and discussed the meaning of SN in general and with specific reference to the higher education sector. SN tool is an essential and necessary tool for students as it assists them to acquire the skills necessary for their studies and for their future workplace. The SNEM was introduced in the entry to attract academic attention regarding the implementation of SN in assessments and activities and to reduce the risks and increase the benefits associated with SN in the education sector. Finally, this is a call for academics to use SN in assessments and activities, since this tool can offer outstanding benefits to students. However, SN can pose several risks. Therefore, when introducing any SN tool into the higher education sector, especially for assessments and activities, a model should be implemented to help ensure the success of SN in this context and to achieve the unit goals. Most importantly, this tool has the potential to assist, encourage, and motivate students to achieve their goals and acquire the skills necessary for their studies and in their future workplace. In the future further research will be carried out by the author to implement SNEM via diverse tools, i.e., blogs, Twitter, and other technologies, to compare and contrast the benefits and risks of these tools.

Cross-References

- [Collaboration and Social Networking](#)
- [Creative Commons](#)
- [Teacher Education, Thinking About ICT](#)
- [Wikis as a Collaboration Tool](#)

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Social Networking Site

► [Facebook Use in Malaysian Higher Education Classroom](#)

Social Networking Sites

► [Social Media for Tertiary Education](#)

Social Networking Sites (SNS)

► [Predicting ICT Skills and ICT Use of University Students](#)

Social Networks in Higher Education Management

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Definition

A social network is a web-based application, a system of open relationships and exponential growth. On a social network, a user invites other users to establish an online connection via the platform. In turn, each user also creates their own group of contacts to create a network of connections (Assimakopoulos et al. 2017; Cheung et al. 2011). In the educational arena, a social network can also be a tool to support management decisions.

Introduction

In recent years, universities have faced various changes and circumstances that have affected the formulation of strategies and operational management. Among such changes – varying in nature and geographical scope – are, for example, economic changes, changes in the regulation of the education system, or the internationalization of education (i.e., Daniel 2015; Uslu 2018). In this context of change, the digital context generates new challenges and opportunities that influence different areas of the university's organization (academic level, provision of services, administrative management, relationships with stakeholders, agreements with other universities, etc.). Moreover, the technological revolution has influenced the way in which the current role of universities in society could be understood and how that role can be developed (Sadowski et al. 2017; Voss and Kumar 2013).

One of the digital options with an increasing presence in the world of higher education is the use of social networks (Peruta and Shields 2017; Voss and Kumar 2013). Social networks establish bidirectional relationships between users of the platform but also nodes that create a chain of relationship points and connections, creating communities. As a main purpose, social networks allow the creation, publication, and exchange of content. These contents can vary in nature (information, opinions, photos, videos, etc.) and purpose (educational, professional, social, cultural, economic, etc.). The interactivity and dialogue of this type of service, based on technology and functioning within a network, encourages users to produce content (producers), receive content (receivers), and discuss and share content (opinions, suggestions, links, etc.) (i.e., Boyd and Ellison 2007; Kane et al. 2012; Sobaih et al. 2016). Therefore, on social networks users expose themselves, accepting the rules of the game – give, receive, and contribute – and creating diverse and enriched digital scenarios. Thus, social networks allow the user to do the following, among others:

- Publish content of interest (news, articles, reports, etc.) in various formats (text, videos, photos, etc.)
- Create content from the content of other users, generating new knowledge.
- Collaborate with third parties, facilitating teamwork and sharing.
- Share content with other users of the social network, creating a sense of community.
- Relate to other individuals, responding to the needs of the individual as a social being.
- Learn from the content of other users.
- Strengthen personal self-esteem through publication, debate, and content defense.

There are a significant number of social networks, in terms of objectives, target audiences, and the platform's resources (Moreira et al. 2017). With general or horizontal social networks, users maintain contacts and converse on multiple topics (Facebook, Twitter, Google Plus, Instagram, etc.). As vertical social networks, there are specialized social networks that deal with specific topics, such as cinema (CinemaVip) and crafts (Ravelry), and professional networks are aimed at connections and professional contacts (Lindkedin, Viadeo, About.me, etc.).

Social Media Networks in Higher Education

The use of social networks has a growing presence in university life. Thus, it is common for universities to link the various social networks on which they have a presence on their websites. These networks include, for example, Facebook and Twitter. However, social networks must be considered as more than just technological resources but also as strategic allies. The university must be horizontal, integral, constructive, global, transparent, collaborative, international, and so on, and, in this sense, social networks contribute to this reality. After examining some examples of the application of social networks in university management, a model of the integration and development of social networks in higher

education institutions is proposed. This model aims to establish a frame of reference for the integration of social networks into the mission, vision, strategy, and action of universities.

Social Networks in Teaching: A New Teaching-Learning Model

In the last decade, the educational model for universities has focused more on the individual needs of the student. This new work scheme aims to promote, among other issues, the autonomy of students, collaborative work, continuous learning, critical thinking, social skills, and creativity. Brown (2012) and Arquero and Romero-Frías (2013), among others, recognize that new technologies represent these values. Thus, social networks have an important role in this new educational context because, among other reasons, twenty-first-century students are “digital natives.” Indeed, in general terms, university students use social networks in their daily lives and are receptive to any technological innovation. Among the most widely used social networks, both personal and academic, are Facebook and Twitter. The use of social networks in the teaching-learning process generates important advantages and possibilities (Sobaih et al. 2016; Arquero and Romero-Frías 2013; Demir 2018; Lambić 2016; Sharma et al. 2016). This paper emphasizes the following advantages:

- Access to academic material (lectures, exercises, etc.)
- Access to academic achievements (student's exam scores, evaluation of group activities, etc.)
- Share academic resources with one another.
- More personal and interactive communication with teachers and classmates.
- Work cooperatively by creating study groups.
- Continuous awareness of changes to timetables and the content of subjects.
- The expanding and enriching of content and ideas through debate and sharing.
- Continuous and dynamic relationships with teachers and classmates.
- More dynamism in the teaching-learning process.

- Receive support and academic advice in real time.
- Use and master technological tools and applications.
- Provide informal work environments in which to learn outside of the classroom.
- Nurture feelings of social belonging and community.
- Resolve doubts and clarify concepts as soon as the need arises.

Likewise, the use of social networks in the teaching-learning process influences academic results such as, for example, greater mastery and understanding of the subjects, more motivation and student satisfaction, a positive work climate, and better interpersonal relationships between students and teachers.

Social Networks in Research

Social networks play an important role in the field of scientific research. In this context, scientific publications, through their social networking platforms, have had an increasingly important impact on the academic field. Examples of social networks in research include Academia.edu, ResearchGate, Mendeley, or MyScienceWork. In addition, scientific networks are connected to other networks such as Facebook and Google Plus, which further increase the possibilities of visibility, connection, and interactivity. The advantages offered by this type of social network are numerous and relevant for the curricular development of the researcher within the academic world (Al-Aufi and Fulton 2014; Meishar-Tal and Pieterse 2017; Muscanell and Utz 2017; Roig-Vila et al. 2015). Among the possibilities that scientific social networks can offer are, among other things, the following:

- Upload and download of articles and abstracts.
- Share of research ideas and expertise.
- Academic visibility and greater scientific impact.
- Up-to-date information from publications in a scientific field.
- Belong to a related scientific community.

- Receive notifications of scientific events (conferences, lectures, etc.)
- Read recommendations to publish in scientific journals.
- Receive notifications of job opportunities in the academic field, such as posts at universities and research centers.
- Participation in scientific discussion groups.
- Get ideas and answers to research related questions.
- Follow other researchers (e.g., new publications).
- Know who and how many people have shown interest in your own publications.
- Access to specialized mailing lists.
- Create groups and workspaces at different levels (departmental, institutional, etc.)

As a result, researchers can raise their profile and professional prestige, consolidate their digital identity, and increase the possibilities of collaboration agreements or participation in projects or publications, among other benefits. Likewise, universities also obtain a greater presence and scientific prestige, improving their position in rankings, which also leads to an increase in student enrollment, agreements with other universities, university-business collaborations and agreements, and funding.

Social Networks in University Communication

Universities must be increasingly competitive, so they must enhance their brand image and international projection through an appropriate communication strategy. Information and communications technologies represent a communication channel that offers diverse resources and formats that enrich the message and reach many more recipients at a lower cost relative to traditional media. As an example, a digital option widely used by universities for communication purposes is corporate websites. Other options are social networks that contribute toward making communication more interactive and creating a sense of community, making the message participatory and collaborative (i.e., Alexa et al. 2012; Bélanger et al. 2014).

Regarding the use of social networks for university communication, universities have the possibility with social network sites to publish information using a wide range of multimedia resources (Galan et al. 2015; Peruta and Shields 2018; Le et al. 2019). Thus, universities can present their objectives and university policy (university mission, regulations, reports, minutes, financing, corporate social responsibility, etc.), academic information (subjects, teaching staff, teaching resources, curricular offer, etc.), management data (services, organization, schedules, results, etc.), extracurricular activities (special days, concerts, sporting events, conferences, exhibitions, job offers, etc.), and much more. The format of the content can be diverse, including text, videos, photos, links to other websites of interest, etc. On social networks, the content published by a university is enriched with messages, comments, links, videos, likes, and shares contributed by other users (students, companies, public bodies, etc.). Indeed, social networks are bidirectional, dynamic, and interactive. In this regard, their users expect to play an active role in the content and operation of the platforms. For this reason, universities must promote proactive and reciprocal communication and be open to suggestions and requests, inviting the contribution of content to the university community and always improving their own content and the format in which it is delivered.

In addition, communication on each social network is different and must be managed in different ways. Thus, for example, it is not the same to communicate on Twitter as on Facebook, since the number of characters influences the content of the message and each social network has different resources. Thus, the objective of communication on Twitter is to deliver brief and concentrated messages with quick responses. Facebook, on the other hand, is a more complex network with more digital resources (Al-Bahrani and Patel 2015; Tess 2013). For this same reason, social network users often use several platforms because they offer different services and resources and satisfy different objectives. As a consequence, universities must choose a combination of social networks according to the preferences of their

stakeholders, the resources and technological possibilities provided by each network, and the suitability of each platform for their communication strategy.

Social Networks in the Management of University Services

Universities are increasingly incorporating social networks into diverse services and operations. In this regard, the advantages of social networks in university life are numerous. The following are some examples of this reality.

Enrollment and guidance for the student. Universities design strategies to attract new students each academic year. Within the current range of options, universities publish information on their websites, create information brochures, organize open days, and visit centers of secondary education. One way to increase the number of students is to make use of different social networks. As indicated by Alexa et al. (Alexa et al. 2012), social networks could help prospective students to value the academic offer and evaluate the services and resources of the university, among other issues, so they can make more well-informed decisions. Therefore, it is important that students have guidance and support at all times (Sobaih et al. 2016; Koshkin et al. 2017). Moreover, the optimal management of the university's presence on social networking sites relies on its followers to positively identify with the university so that they will be more predisposed to enroll and make positive comments to other potential students. In this regard, while prospective students can find much of the information they require on university websites, social networks are interactive and collaborative environments. Consequently, social network users demand quick answers and close proximity, and, as Voss and Kumar (Voss and Kumar 2013) stated, universities should listen and answer promptly to their audience through social media. For this reason, universities must include interactive spaces on these platforms with academic and administrative staff ready to answer any questions, resolve any doubts, and meet the demands of potential students. On the other hand, universities must choose the appropriate message object for each type of social

network. Thus, to attract potential undergraduate students and young students, it could be appropriate to design messages for Facebook and Twitter. However, for postgraduate studies (masters, doctorate, specialized courses, etc.), the university promotion strategy could also focus on professional social networks such as LinkedIn.

International dimension. In recent years, the international dimension of universities has increased thanks, for example, to exchange programs, with social networks being an effective way to attract potential foreign students. To this end, universities should use social networks to provide these students with information that helps them make the right decision, offering different options (academic offerings, university residences, language schools, transportation, financial information, etc.) in different formats (text, videos, photos, etc.) (Le et al. 2019; Hamid et al. 2016; Vrontis et al. 2018). In the same way, universities must manage spaces of consultation on their social networks and respond as quickly as possible to all questions posed by students from abroad and in many different languages. The strategy for attracting foreign students and helping them in the process of registration would need to be coordinated with those responsible for exchange programs and international relations at each university. Finally, one way to attract students is to make it easier for social network users to tell of their experiences with the university.

Library services. University libraries have found on social networks an ideal digital medium for the development of their services. As example, Martin Marichal (Martín-Marichal 2013) shows that the use of different social networks (Facebook, Twitter, YouTube, Instagram, etc.) by Spanish university libraries is significant. This also contributes to the fact that a large volume of bibliographic material can be offered in digital format, such as e-books and online scientific articles, in a virtual environment. Regarding the type of content and resources available at academic libraries, there is a wide range of options, as recognized by Collins and Quan-Haase (Collins and Quan-Haase 2014) and Phillips (Phillips 2011), among others. Thus, on social networks,

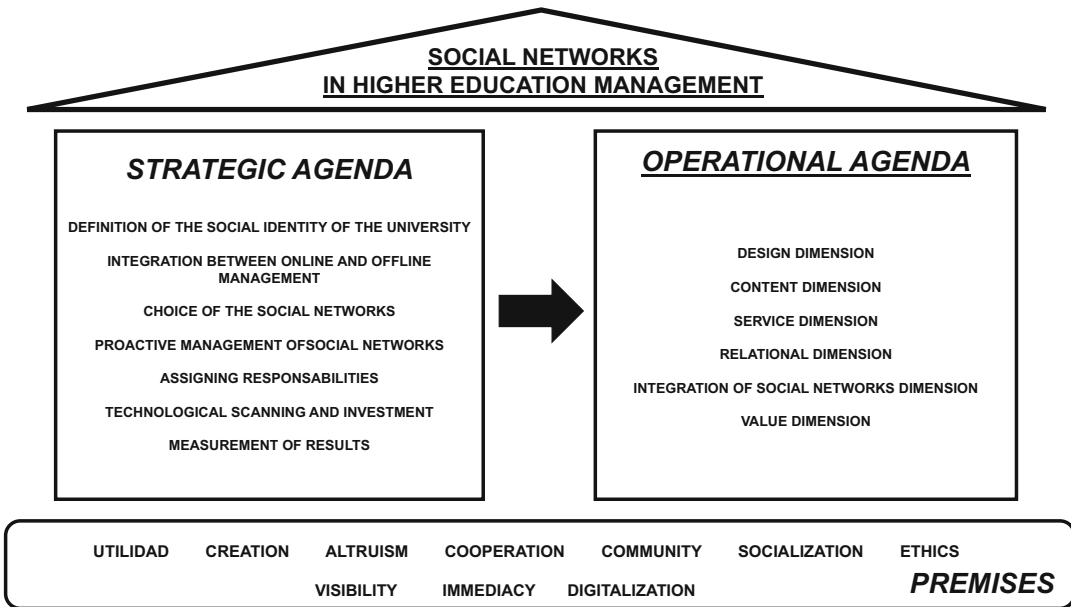
libraries can transmit information about their services, provide access to catalogs, offer training courses, communicate schedule changes, and much more. In terms of multimedia, libraries can post photos and videos and links to other social networks and websites of interest. Information about academic, cultural, and/or social events happening at the university or elsewhere, such as conferences, shows, cinema showings, etc., can also be published. At the level of customer service, users can raise complaints and make suggestions, answer surveys, provide comments (hashtags), Participate in blogs, etc. In addition, libraries could create communities by inviting companies, public bodies, etc. to participate in their network, contribute value to the wider interests of the university community by publishing news of interest, and allow the users of the network to share experiences (literary, sports, gastronomic, etc.), among others. With all this, these platforms generate a continuous and dynamic interaction between the library and users of the social network, enhancing commitment to and identification with the university and making more effective use of university resources.

University Management Based on Social Networks

Based on the above, a social network management model is proposed at the university level, applicable to all spheres of action and to all interest groups (Fig. 1). First, the premises that must support the use of social networks, both at a strategic and operational level, are established. At a strategic level, the implications of the use of social networks are explained, not as a passive resource but as key factors in the new university management model. At the operational level, a series of recommended content and format features are described in the configuration and use of social networks.

Premises of Social Networks

The optimal use of social networks is characterized by a series of parameters or intrinsic qualities, as derived from Voss and Kumar (Voss and Kumar



Social Networks in Higher Education Management, Fig. 1 Social networks in higher education management

2013), Boyd and Ellison (Boyd and Ellison 2007), and Meishar-Tal and Pieterse (Meishar-Tal and Pieterse 2017), among others. This paper proposes a series of values that should serve as a frame of reference when higher education institutions use social networks in any field of their university activity.

- *Utility.* Social networks must offer useful content to users.
- *Creation.* Content contributed by a user generates new content by other users in the form of opinions, comments, links, uploaded documents, etc.
- *Altruism.* A priori, the economy of social networks is the “gift economy.” Put simply, users share content for free.
- *Cooperation.* Social networks are based on collaboration and user participation.
- *Community.* Social networks serve as a connection hub between users, creating communities.
- *Socialization.* People who participate in social networks seek to build relationships, that is, a connection with other people, whether academic, professional, scientific, or social.

- *Ethics.* Social networks are based on ethical principles of transparency, responsibility, and respect, among others.
- *Visibility.* Social networks represent an opportunity for projection and visibility, so the impact of behavior on the network is important.
- *Immediacy.* The response time in social networks has to be as short as possible. The user expects to receive an answer almost immediately.
- *Digitalization.* Users of social networks dominate, or are sensitive to, the development of new information technologies.

Strategic Agenda: Management Approach

The strategic agenda includes considerations regarding the management of social networks within the university environment, representing a frame of reference and antecedent for the implementation of the operational agenda. Authors such as Bélanger, Bali and Longden (Bélanger et al. 2014), Dumpit and Fernández (Dumpit and Fernandez 2017), and Sobaih et al. (Sobaih et al. 2016), among others, have contributed to the understanding of the management of social

networks from an integral perspective. In this model, the following is proposed:

- *Definition of the social identity of the university.* Universities must analyze, on the one hand, how new information technologies contribute toward developing their strategy and corporate image and, also, how they can improve them. In other words, these types of institutions must study how social networks allow their strategy to be implemented and, also, how they can influence their future plans. To do this, the current and potential use of social networks by different interest groups at the university must be known. Likewise, benchmarking exercises must be carried out, reviewing and monitoring current uses of social networks at other universities.
- *Integration between online and offline management.* Universities should integrate online management with offline management in order to maximize organizational efficiency and available resources. Thus, for example, social networks keep students informed of changes to class schedules, allow users to make complaints and suggestions about the operation of university services, and ensure that the educational offer has greater international projection. Universities must decide on the scope (objectives, activities, interest groups, etc.) of both online and offline management, that is, the synergies and differences between both scenarios.
- *Choice of social networks.* Universities should know the value or utility that each social network can bring to the university's objectives. Based on this, each institution must choose the optimal combination of social networks for their organizational identity. Moreover, the role of each social network and the interrelationships between them should be analyzed. For example, whether the same type of content will appear on different social networks. In addition, universities must identify which network or social networks are suitable for each interest group and according to which roles. Thus, educators can use Facebook in the teaching-learning process as teachers and ResearchGate as researchers.
- *Proactive management of social networks.* Universities should analyze the risks and opportunities that each social network provides in advance. From there, each institution can plan content for and the format of each social network and give balanced responses to its different stakeholders at all times. Furthermore, universities must perform market tests and monitor the results on each platform, that is, implement a system of quality control for each social network and act quickly to modify any content or format in case of negative or unwanted effects. In other words, the continuous improvement of the university's performance on social networks should be promoted.
- *Assigning responsibilities.* Universities must assign responsibility for the management of social networks. Among other functions, the individuals assigned to this task must work in coordination with university management in order to decide the university's strategy and its development. These teams must work together with the various interest groups to identify their needs and demands regarding the design, operation, and use of social networks.
- *Technological scanning and investment.* The team responsible for the management of social networks must invest in the necessary technological resources (e.g., WiFi) and offer training on how to use social networks to the different interest groups of the university. Thus, universities must provide the technological bases that are necessary to facilitate and maximize the use and value of social networks. This technological "scanning" should be done proactively in order to identify new digital trends and evaluate the capacity of each social network to provide benefits to current and potential university community members.
- *Measurement of results.* Universities should measure the impact of social networks in relation to their objectives. Thus, for example, metrics such as the number of "followers" and "retweets" can be tracked to measure the interest generated by any published content. Moreover, extensive studies can be carried

out aimed at asking students which social network provided useful information or generated more interest on a topic.

Operational Agenda: Parameters of Quality on Social Networks

Given the great diversity of social networks, there is no ideal model for the management and design of content. However, social networks are digital platforms that, therefore, require features similar in nature to other digital scenarios. From the results obtained in different studies on the functioning of social networks and from the perspective of service quality (Ellahi and Bokhari 2013; Rauniar et al. 2013; Wu et al. 2015), and some reflections on the proposed strategic agenda, a series of important recommendations for this model are proposed:

- *Design dimension.* Legible format, ordered structure and distribution, logical and intuitive operation, the presence of navigation elements (menus, navigation bars, etc.), and an attractive and modern design.
- *Content dimension.* Relevant content, updated information, entertainment (games, contests, etc.), and diversity of multimedia formats.
- *Service dimension.* Guarantees of security and data protection for users, education and maintenance regarding the ethical behavior of users, support for doubts and problems regarding use of the platform, and quick response times.
- *Relational dimension.* Continuous adaptation to the needs of users, proactive attitude to boost the network and capture the attention of users, management of positive and negative comments, and transparency.
- *Integration of social networks dimension.* Appropriate choice of messages on different social networks and consistency (at the content level) between messages displayed on the various platforms (corporate website, Facebook, Twitter, etc.)
- *Value dimension.* Analysis of comments on the social network to make improvements in online and offline management, innovation on technological resources, design new products, and services at university.

Final Reflections

Currently, platforms such as Facebook, Twitter, and ResearchGate – among others – play an important role in numerous universities. The diverse interest groups represented by universities (teachers, students, administration and service personnel, etc.) can participate in networking on the social networks that have a presence at the university and gain access to a large range of multimedia content (academic information, offer of services, news, videos, etc.), as well as help to build new knowledge (opinions, providing news, expanding information, sharing experiences, etc.).

We can speak of “network of networks,” where the digital space becomes a collaborative, transparent, and enriched environment and one network leads to another (e.g., a Facebook post appears on Twitter). Furthermore, the same interest group can use several social networks, for example, when the academic staff uses different social networks for different organizational roles. Subsequently, universities must provide multi-level online scenarios as a map of social networks. With this, the various members of the university community can interrelate in virtual spaces in a dynamic, interactive, and continuous way according to their particular interests – mainly, on academic, scientific, business, cultural, and social issues.

Social networks contribute toward strengthening the image of the university and the development of its mission and organizational strategy. Indeed, social networks favor an open, multicultural, committed, innovative, and globalized university model, which influences the wording of the “raison d’être” of the institution and its values and expectations. In addition, these platforms improve the effectiveness and efficiency of universities, that is, they allow them to fulfill their objectives with the maximization of available resources. Moreover, social networks can contribute to improving the strategy and future functioning of universities.

From the resources offered by each social network, universities should, as far as possible, create spaces that are logical, ordered, intuitive, and safe.

They must also provide content of interest and allow users to create new content. Furthermore, universities must be receptive to all kinds of ideas, suggestions, and comments that are expressed on social networks, using constructive and positive language. Above all, the management of social networks must create value for its users, for example, by improving the university's academic and service offerings. Together, this paper presents a model that to provide a frame of reference for university management in the context of social networks.

Summary

In terms of economic, social, and cultural impact, few digital innovations have been quite as influential as social networks in recent times. These platforms are an ideal channel of communication through which to publish, share, and comment on content in various formats, creating communities of users in the process. In this way, social networks can contribute toward consolidating a constructive, participatory, and socially oriented university model.

The present work presents a model of university management of social networks that starts from a series of basic premises on which to develop a strategic and operational agenda. The basic premises correspond to the principles that characterize social networks and that should be included within their set of organizational values. Based on these principles, in the strategic agenda, the university must establish how to include social networks in its strategic and operational management. In this regard, social networks are not only a technological resource that supports the performance of the university but should also be included in the formulation of the institution's strategy at all levels (academic, services, relations with other universities, relations with society in general, etc.). The operational agenda proposes a series of recommendations to increase the quality of the browsing experience on social networks, both in format and content.

Cross-References

- [Blended Learning](#)
- [IT in Educational Institutions, Planning and Development of](#)
- [Learning Management Systems, An Overview](#)
- [Social Media and Networks as Digital Instruction and Learning Platforms](#)
- [Social Networking](#)
- [Technology Enhanced Learning](#)

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Software Development Methodologies, Educational Software Development Processes

► [Software Development Processes Designed for First Year Computing Undergraduates](#)

Software Development Processes Designed for First Year Computing Undergraduates

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Synonyms

[Software development methodologies, educational software development processes](#)

Introduction

The increasing use of computing and mobile technologies over the past 15 years has had a dramatic impact on both personal and professional lives. This rapid growth in technologies has also increased the demand for skilled software developers, and this demand is increasing on a global scale. A report from the United States Department of Labor (2015) states that employment in the computing industry is expected to grow by 12% from 2014 to 2024 which is a higher statistic than the average for other industries.

Despite this demand for computing graduates, it is recognized that a significant barrier for increasing the numbers of computing graduates lies in the inherent difficulty of learning how to develop quality software. This difficulty has resulted in significant failure rates globally in computer science programs (in comparison to other disciplines) over the past decade and which speak to a lack of competency being achieved by

students particularly in software development (Watson and Li 2014). Running in tandem with failure rates, there are also significant issues associated with the retention of undergraduates in computing programs (Petersen et al. 2016). Both of these issues have resulted in a very active research community in computer science education at third level, specifically at the first year level, as this is where many of the issues with retention and competency first occur.

If students are to become competent in software development, it is widely accepted that teaching students how to problem solve and generate solutions in a structured way is vital in enabling them to develop proficiency (Morgado and Barbosa 2012). Being able to solve problems that require a software solution in a structured way implies the use of a software development process. This is a mechanism which informs a software developer of the steps and stages involved in developing quality software from initial analysis to final design and implementation (Boehm 2006). However, even though there are many processes available for experienced developers (e.g., *Agile* processes), very little work has been carried out on developing appropriate processes for first year, third level learners who have little or no prior programming experience (Caspersen and Kolling 2009). The reason for this deficiency is due to the problematic nature of teaching software development to inexperienced learners as using a software development process assumes that the learner has preexisting programming knowledge so they understand computational constructs such as iteration and modularity. This makes the use of formal processes difficult for educators of introductory software development courses and produces a conundrum of how to support students in the use of development processes in the absence of such programming knowledge. This presents a vacuum for educators which means that the process of developing software solutions is typically taught very informally and implicitly on introductory courses at third level (Coffey 2015). In practical terms, this means that analysis and design is often treated very casually on such courses with the focus instead being on the teaching of syntax without providing adequate strategies to

formulate designs for programming problems. In such an environment, it is natural then that the primary focus of such courses gravitates towards the teaching of programming concepts, with the topic of development process coming later in the course or in later years.

The problem with this focus is that it does not support students in the acquisition of good development habits and practices as novices have a natural inclination to focus on the surface features of a problem in order to fit what is known about the problem into their existing knowledge. This means that novice developers will often jump straight into implementing some aspect of a solution without any planning because they can find it difficult to separate ideas for solutions from the implementation of those ideas (Kokotovich 2008). This can lead to the adoption of maladaptive cognitive practices in software development (e.g., coding by rote learning) which can be very difficult to unlearn and can ultimately prohibit student progression in the acquisition of software development skills (Huang et al. 2013). It has also been found that poor practices in planning and designing software solutions acquired in the first year can persist even to graduation (Loftus et al. 2011). Therefore, it follows that if a software development process is incorporated explicitly in an appropriate way into introductory courses to scaffold students in software development, this could limit the development of such maladaptive practices. A systematic process should not only help those students who have fundamental problems arriving at a solution but should also improve the quality of solutions for all students. This view is echoed by De Raadt et al. (2009) who suggest that students will perform better at software development when they are taught explicit strategies for design rather than such strategies being an implicit part of the syllabus.

In order to understand the characteristics of software development processes both in industry and in third-level education, the following sections will examine the most common processes used in both domains before suggesting some core components that could be used in the generation of an educational software development process aimed at novice, third level learners.

Software Development Processes in Industry

Research into the production of software development processes for commercial use has been a robust and very important area of research and growth for the software development community for the past 30 years (Pathak and Saha 2013). Having a well-defined process ensures that software can be developed in a systematic fashion where there is traceability from problem specification right through to final work product; all work can be measured and thus improved. There are many different software development processes available for use in the software industry but they all follow the basic stages outlined in Table 1 albeit in different configurations and execution.

Two principal categories of process have dominated the software industry over the past three decades. The first category is the *Software Development Life Cycle (SDLC)* process. This is the oldest and most generic category of process which executes the stages as outlined in Table 1 in a strict sequential fashion since its inception in the 1980s. However, in the intervening years, there have been many improvements and

Software Development Processes Designed for First Year Computing Undergraduates, Table 1 Core stages of a software development process

<i>Preliminary analysis</i> – This first stage allows for an initial investigation of a problem in order to discover the principal outcomes and goals of the problem. This investigation is typically coupled with a feasibility analysis in terms of costs, time, and personnel
<i>Requirements definition/systems analysis</i> – Once the problem has been deemed feasible, this stage investigates what needs to be done in order to solve the problem. This will involve understanding the functional requirements to solve the problem
<i>Design</i> – This stage focuses on designing potential solutions for each of the requirements
<i>Implementation</i> – This stage uses the work products from the design stage as a guide to implement software
<i>Integration and testing</i> – In this stage, individual software units are tested and integrated into a final working solution
<i>Maintenance</i> – This final stage involves continuous improvement of software after deployment

amendments made to this process. This has included the realization that due to the complex nature of eliciting user requirements, gathering fixed requirements up-front that then cannot be changed or improved later in the project is unfeasible and can lead to unusable systems. A more effective route is to allow steps to be retraced to allow for evolving requirements.

The second principal category of processes is Agile which is arguably the most popular and widely used methodology in current commercial software development (Bustard et al. 2013). Agile emerged in the 1990s as an attempt to more formally deal with higher rates of change in software requirements as well as customer expectations and the high perception of project mismanagement that existed at the time. The main characteristics of processes based on this category have their origins in iterative and incremental development and involve breaking development work into small increments to minimize the amount of up-front planning and design. Iterations are short time frames that typically last from 1 to 4 weeks and involve a team including a customer representative(s) who work on all stages of developing the increment from planning through to testing. From an educational perspective, it has been found that the nature of fast, iterative development of Agile makes the inclusion of such processes (such as XP, Scrum) into third level curricula more appropriate to students in their final or penultimate year of undergraduate study where they have a degree of experience and proficiency in software development.

This section provided an overview of software development processes used in the software industry; the next section examines the use of software development processes at third level.

Software Development Processes in Third Level Education

It is only natural that evidence-based processes based on SDLC and Agile would be considered appropriate for use in third level educational courses. However, as was established in the introduction to this entry, the use of such processes

presuppose a thorough understanding of standard programming constructs which inexperienced third level learners will not have. Therefore, it is clear that processes aimed at this cohort of learners must take this lack of experience into account while also incorporating the basic stages of software development (see Table 1).

In examining the literature for software development processes aimed at inexperienced third level learners, it was found that despite the wealth of established software development processes aimed at experienced developers working on large projects, there are comparatively few available for introductory, third level computing courses. This relatively small number of processes is most likely due to the difficulty of juxtaposing a lack of programming experience with the use of a software development process. Table 2 provides a summary description of some of the more widely publicized of these educational software development processes.

One noticeable feature of the processes described in Table 2 is their specific focus on a particular aspect of the process. For example, the STREAM process (Caspersen and Kolling 2009) focuses on design in an object-oriented environment; the P³F framework (Wright 2012) also has a focus on software design and aims to arm novice designers with expert strategies; the process by Hu et al. (2013) has an emphasis on generating goals and plans and converting those into a coded solution via a visual block-based programming language; POPT (Neto et al. 2013) has a focus on supporting software testing; and Morgado and Barbosa's process (2012) aims to support students through all developmental stages with the use of template forms coupled with an instructor supplied prototype to aid understanding of the problem. These examples suggest that there is a gap in the research for a process aimed at novice learners that supports all aspects of developing software solutions with a focus on the learning and utilization of developmental constructs and problem-solving skills.

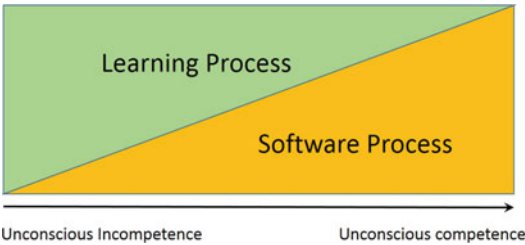
The following sections build the case for an educational software development process by highlighting the principle requirements of such a process.

Software Development Processes Designed for First Year Computing Undergraduates, Table 2 Educational software development processes

Software development process	Description
STREAM – Stubs, Tests, Representation, Evaluation, Attributes, and Methods (Caspersen and Kolling 2009)	This process has a focus on incremental development in an object-oriented environment with Java as the implementing language. It contains six clear stages that allow students to incrementally build up a solution to a problem
P ³ F framework – Principles, Patterns, and Process (Wright 2012)	This process has a focus on design. It uses four elements to allow students employ expert design strategies such as design patterns to ensure they design efficient and sustainable solutions
Programming methodology (Hu et al. 2013)	This process has a focus on the planning stage of development. It uses a five-stage process to facilitate students to create plans and goals for their solution to ensure they fully understand the nature of the problem. Plans are developed using a block-based language similar to Scratch
The Morgado and Barbosa approach to solving programming problems (Morgado and Barbosa 2012)	This process has a focus on planning and design. It contains two stages supplied with rules that allow students fill in template forms to help with their planning. A prototype solution of the problem is supplied by the instructor
POPT – Problem-Oriented Programming and Testing (Neto et al. 2013)	This emphasizes the importance of testing in software development and supplies steps for planning and undertaking tests

A Framework for an Educational Software Development Process

Prior to the development of a software development process, it is important to formulate a framework on



Software Development Processes Designed for First Year Computing Undergraduates, Fig. 1 From learning process to software development process. (Source: Author)

which the process will be based. The role of this framework is to guide the context and content of the resulting software development process.

The first issue that requires attention is in understanding the context in which the software development process will be used. This is an environment where freshman, undergraduate students typically have little or no programming experience and are learning how to develop software solutions in a systematic fashion. This raises an interesting question – should students be taught how to program first and then be introduced to a software development process or should programming concepts and skills be taught as part of a process? This research takes the latter view as teaching students how to program independently of process runs the risk of students developing poor development habits that become ingrained by the time they learn a process. Therefore, the software development process should scaffold so that it inherently encompasses a learning process which can slowly fade as students gain expertise of developmental concepts, practices, and grow their self-efficacy. The relationship between learning process and software development process is visualized in Fig. 1 where Maslow’s (1970) four stages of learning model are used to timeline the progression of learning.

At the start, the learner is categorized as an unconscious incompetent who does not know what they need to know so the software development process is heavily scaffolded as a learning process where the students are guided to use the software development process to fully solve a suite of problems that are appropriate to each

stage of their learning. By the time the learner has gained experience of the concepts and practices, the scaffolding of the learning process will be removed to allow the learner continue to use the software development process in solving new and more complex problems as they expand their learning and continue their journey towards becoming unconscious competents.

Once the context of the environment is understood, it is important that the details of both the learning process and software process (see Fig. 1) are fully teased out.

A Learning Process

A learning process should contain the *knowledge*, *skills*, and *attitudes* that constitute the essential learning elements required to develop software solutions as well as encourage a positive mental disposition for learning.

In order to identify the *Knowledge* component of the process, it is important to state that this process should be applicable to a variety of imperative, commercial languages typically taught in introductory, third-level courses. Therefore, the content in the process should not be language specific but should capture the essential content that forms the basis of such languages in a generic fashion. Such content typically includes:

- 1. The declaration of variables and sequential flow using these variables (e.g., input/print/assignment)
- 2. Nonsequential flow of statements including conditional and iterative constructs
- 3. Modularity to enable code optimization and reuse
- 4. Object interaction (if the development paradigm is object oriented)

While these four areas would make up the essential knowledge component of any learning process, it is worth exploring a mechanism that that can provide a lens into the student learning liminal journey (both cognitive and affective) with the aim of guiding them into becoming more proficient and confident at solving programming problems. The theory of threshold concepts can provide such a lens.

Threshold concepts (TCs) have been proposed as a way of characterizing the progression of learning by students in any subject area. Land et al. (2005) suggest that within each subject, there are certain concepts that are difficult to grasp and are troublesome but once mastered, they act as a portal that can open up a new way of thinking within the subject area that is transformative and irreversible. They also state that “crossing the threshold” to understanding these concepts is a necessary step if students are to advance and become proficient in the subject area. In examining the research carried out into TCs for computing, it is clear that there is not a consensus on a list of TCs for this area and the principal research into identifying TCs in computing have been mainly carried out by a group of European researchers (Sanders and McCartney 2016). In examining all of the published research on the identification of TCs for computing, there are two concepts that emerge as having consensus to date. The first is *program dynamics* meaning having a mental understanding of the dynamics of state and program/algorithm execution and the second – only relevant in an object-oriented paradigm – is *object behavior*. It can also be argued that *object behavior* is a subset of the concept of *program dynamics* (when the development paradigm is object oriented) as understanding object behavior requires having a mental model of the behavior and state of “live” objects in execution.

Therefore, the declarative knowledge for this learning process will focus on the four essential concepts outlined at the start of this section but will teach them through the lens of program dynamics. These four concepts are now relabeled as threshold concept stages, are coded as TC1 to TC4, and are summarized in Table 3.

Software Development Processes Designed for First Year Computing Undergraduates, Table 3 Threshold concept stages for learning process. (Source: Author)

Threshold concept stages
TC1: State and sequential flow
TC2: Nonsequential flow control
TC3: Modularity
TC4: Object interaction

In order to identify the *Skills* component of the learning process, students must be taught appropriate problem-solving skills that will allow them to solve problems. Computational thinking (CT) is an approach to problem-solving that aims to utilize the strategies undertaken by expert software developers as a mechanism to solve problems in any discipline that require a computational solution. CT was popularized by Jeanette Wing (2006) in her seminal paper although the phrase was originated by Seymour Papert in the context of using the affordances of computer-mediated instruction to help students experiment with – and understand – mathematical concepts. There is a clear distinction in the literature made between CT and programming in that even though programming is a key route to enable CT, the process of CT itself may be applied to solving problems that do not involve a programming solution. The research interest in CT has grown as a result of our ubiquitous technological environment. In such an environment, it is argued that CT is a basic literacy which should be an integral part of the educational process across all educational levels and disciplines where students of all ages can become adept at seeing how problems can be broken down and solved with appropriate computing tools in innovative ways. As a result, there is a lot of active and very interesting research into the teaching and assessment of CT. Much of this research is aimed at first and second level education often in the context of block/visual languages (such as Scratch, Alice, AgentSheets) and game-based learning which is used to teach CT skills to all levels including third level. At undergraduate level, CT is also being researched as a mechanism to introduce computer science skills to noncomputing students. While there is no doubt that the key skills associated with CT are an inherent part of computer science courses which principally teach commercial, imperative languages, there is little evidence in the literature to show that the advantages of CT are being explicitly exploited and incorporated into mainstream introductory software development courses at third level. This suggests that there is an opportunity for computing courses to

explicitly mine the affordances of CT to support introductory education at third level.

Given that research into CT has only been active for the past decade, the topic is still relatively immature and so there is yet little agreement on what constitutes a detailed definition of CT or how it can be assessed. From examining the literature, seven principal skills most commonly cited are: *applying abstraction; data analysis and representation; problem decomposition; evaluating solutions; pattern recognition; generating algorithms; modelling and simulation*. Other concepts such as *iteration, recursion, and parallel thinking* are also suggested by Wing (2006). It is the contention of this author that *iterative* and *recursive thinking* are concepts which form part of declarative knowledge which is then made procedural by the CT skills of *writing algorithms, modelling, and simulation*. It is also felt that *parallelism* is a concept which is too advanced for novice computing students studying in the context of imperative, textual languages. These seven skills are coded as CT1 to CT7 and are summarized in Table 4.

Finally, in order to identify the *Attitudes* component of the learning process, it is important to acknowledge the impact of affective learning on developing students’ belief systems, emotions, and attitudes. One affective factor important in determining the success of students in a software development course is the students’ belief in their self-efficacy in the subject (Bandura 1994). Self-efficacy is a judgment by a person of how capable they are of successfully carrying out a task which influences their choice of activities, the amount of effort they expend, their persistence in

Software Development Processes Designed for First Year Computing Undergraduates, Table 4 CT skills for learning process. (Source: Author)

Computational thinking skills
CT1: Abstraction
CT2: Data representation
CT3: Decomposition
CT4: Evaluation of solutions
CT5: Pattern recognition
CT6: Generating algorithms
CT7: Modelling

Knowledge	Skills	Attitudes
TC1. State and Sequential Flow TC2. Non-Sequential Flow Control TC3. Modularity TC4. Object Behaviour	CT1. Abstraction CT2. Data Representation CT3. Decomposition CT4. Evaluation of solutions CT5. Pattern recognition CT6. Generating Algorithms CT7: Modelling	AI1. Balanced Self-Efficacy

Software Development Processes Designed for First Year Computing Undergraduates, Fig. 2 Elements of a learning process required for an educational software development process. (Source: Author)

overcoming difficulties, and ultimately their performance outcomes. Individuals with strong self-efficacy believe that they can succeed in challenging tasks which means that they are motivated to attempt such tasks and have confidence as they begin the journey to completing the task. Studies in the theory of self-efficacy have found it to be malleable meaning that it can be changed particularly in introductory courses to improve performance. Suggested routes to improving self-efficacy include supplying clear instruction of the strategies required at each step of the problem-solving process, presenting mastery models to demonstrate how to carry out a task competently and confidently, supplying coping models to make explicit the difficulties students can experience in carrying out software development and giving useful and positive feedback. While a strong belief system can push learners to exceed their expectations, it is also important that they do not have a distorted view of their actual capabilities. Therefore, it is important that students are able to reflect accurately on their learning and experiences to allow them understand what they know, what they do not know and ultimately gain accurate self-efficacy in their abilities. Students should be helped develop their metacognitive skills to enable them to monitor, evaluate, and regulate their own learning strategies which is an important ability for the development of independent learning, encouraging students to take more responsibility for their learning (Sheard et al. 2013). Therefore, giving students an awareness of their self-efficacy through metacognition and providing an environment to promote a growth in

self-efficacy is a guiding force in the learning process.

In summary, this learning process suggests basing the knowledge required on the use of threshold concept stages, the skills are based on computational thinking skills, and the (student) attitude should result in increased self-efficacy in software development. A diagrammatic overview of the learning process is given in Fig. 2.

In Fig. 1, it was seen that the proposed educational software development process has both a learning process and a software process. This section explores the principal suggested components for the learning process, and the next section examines the principal components of the software process.

A Software Process

In understanding the requirements of the underlying software process in Fig. 1, one of the more appropriate strategies for general problem-solving that can be adapted to a wide variety of educational contexts – including programming – is found in Pólya’s *How to Solve It* (1957). This text postulated that there are four main stages to problem-solving (where the context was mathematical problem-solving): *understanding the problem, making a plan to solve the problem, carrying out the plan, and reflecting on the success of the plan*. The strategy suggested for this software process is a basic adaption of this four stage model.

1. *Understand the problem* – The learner aims to achieve an understanding of the nature of the

problem as well as the goal of the problem. When a learner understands and internalizes a goal, they set expectations that can help push and motivate them to learn the new skills required to achieve the goal. In this way, learners can begin to recognize that with effort, their learning curve can increase.

2. *Break down the problem into task components* – This stage requires the learner to break the problem into a hierarchy with levels of tasks and subtasks which constitutes an analysis of the problem (“What do I have to do?”). These subtasks will be articulated to indicate what must be done as opposed to articulating how it is going to be done. Similar to step 1, there will be a metacognitive aspect to this step to encourage learners to think about what they are doing and why they are doing it. It is important that there is a mechanism for the learner to organize tasks in a visual and sequential way.
3. *Design (and code) each task* – It is recognized that as learners become more proficient and as they start to encounter similar tasks in problems, an automation of procedural knowledge will begin to occur. Therefore, not all tasks will need to be designed so metacognitive planning will need to occur to ensure tasks can be marked as requiring further design or not. For each task that does require a solution to be

designed, this design should be represented graphically in a format that can be directly traceable back to the hierarchy of tasks in stage 2. The generation of the designs and their associated program code will be carried out in an iterative and incremental fashion with each interment tested and integrated into the final solution until the entire problem has been solved.

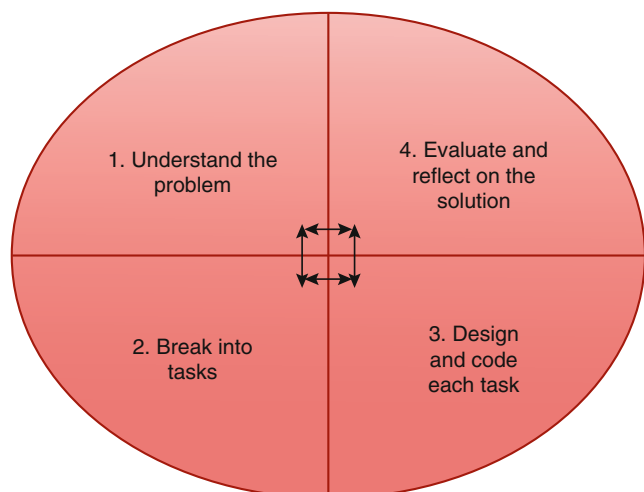
4. *Evaluate your performance* – This final stage tests the final programmed solution and gets the learners to reflect on their performance overall as well as their performance in the individual stages. This will encourage learners in their meta-cognitive abilities to regulate their own learning and move from being novice to expert developers.

The process – summarized in Fig. 3 – will also be supported by an Agile philosophy to guide best practice development practices especially in its use of incremental and iterative development. It is assumed that each stage is iterative and that users can step forwards and backwards between steps as they refine and evolve their solution.

Now that the learning process and software process from Fig. 1 have been explored, these can be combined to form an operational software development process aimed at first year undergraduates.

Software Development Processes Designed for First Year Computing Undergraduates,

Fig. 3 Stages of software process. (Source: Author)

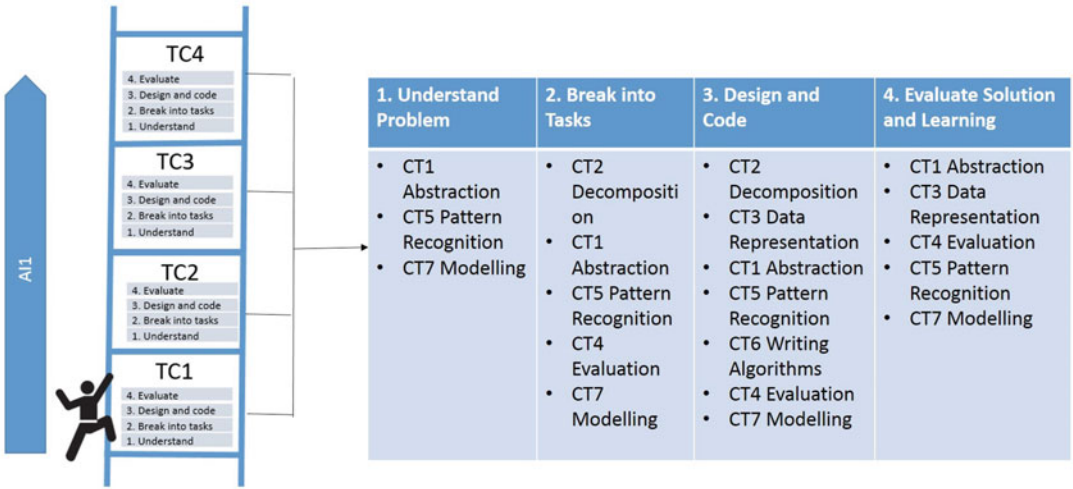


CADET: A Generic Educational Software Development Process

When deciding on an appropriate name for the process, the term “computational design thinking” was examined. This term is currently used in architecture and construction as that industry has moved from computer-aided-design (CAD) to more sophisticated computational processes. It refers to the fact that the affordances of advanced computer technology are creating new types of design processes and new ways of thinking about design. In the context of this research, the term is extended to “*Computational Analysis and Design Engineered Thinking*” (CADET) to refer to the art of software development processes being computer mediated so that the stages of the process produce concrete visual artifacts with which learners can experiment, evaluate, and reflect on as part of their learning. These artifacts should be minimal and should adopt a “just enough” approach to allow learners arrive at solutions in a supported fashion. Therefore, the CADET approach is about learning computational concepts and skills in a computational thinking focused problem-solving environment where the final work product is a verified program. A summary of this process can be seen in Fig. 4.

At the scaffolded learning process stage, learners will work in pairs and will be taught the four threshold concept stages (TC1–TC4) which make up the declarative knowledge. This learning aspect of the software development process is represented as a ladder of learning where each concept is ordered and is a prerequisite to learning the next concept. Each concept is taught via instruction and the computational thinking skills required to utilize the concept are acquired by learners solving a suite of problems using the four-stage software process which is supported by an Agile philosophy. Each of the four stages of the process will use a subset of the computational thinking skills.

Once a (threshold) concept stage is mastered, focus moves to the next concept and the software process is reactivated for another suite of problems relevant to that concept. Once all four threshold concept stages have been taught and practiced, learners will continue to use the four-stage software process with associated computational thinking practices as the basis for software development. This makes this process suitable for learners that have and also that do not have prior programming experience. The software development process is augmented by an online support tool (see Fig. 5) which provides a platform to provide learners with problems to solve for each threshold concept stage as well as diagramming



Software Development Processes Designed for First Year Computing Undergraduates, Fig. 4 CADET software development process. (Source: Author)



Login

WELCOME TO CADET

Computational Analysis and Designed Engineered Thinking



Problem Solving using Computational Thinking

CADET 1.0

Software Development Processes Designed for First Year Computing Undergraduates, Fig. 5 Home page of CADET support tool. (Source: Author)

tools to support their analysis, design, and reflective work.

An external development environment will be used to support the coding stage of the process. While it is expected that learner's self-efficacy will grow and wane as they attempt to solve problems, it is hoped that the scaffolded environment will allow the learner's self-efficacy to generally grow in tandem with their knowledge (identified as A1 in the vertical arrow beside the ladder of learning in Fig. 4). This will be measured by learner reflection.

Each of the four stages of the software process is now described in more detail.

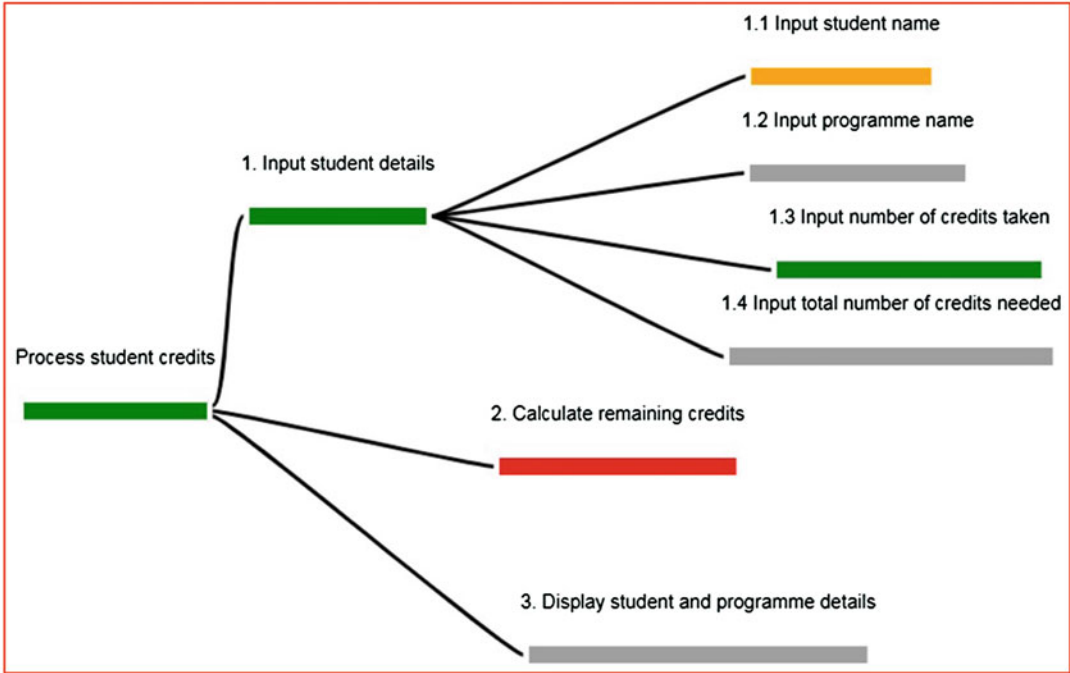
Understand the Problem

In this stage, learners will either be provided with a problem specification (that is appropriate to the threshold concept stage if they are using the learning process) or they can supply their own problem specification and will be invited to articulate their understanding of the problem. This is achieved by

employing the computational thinking skills of functional abstraction to generate a high-level summary of the problem (with its principle goal and outcomes) and pattern recognition to see if it is similar to any previous problem the learner may have solved. This high level summary is recorded in the support tool.

Break into Tasks

This stage employs the computational thinking skills of decomposition to convert the high-level summary and specification from stage 1 into an intermediate set of constituent tasks and to further refine those tasks into more basic tasks. In order to make this stage visual, learners will brainstorm tasks using a mind map with their summary of the problem being the central task (see Fig. 6 for an illustrative example of such a mind map). Mind mapping has been shown to be successful in helping learners to brainstorm (Ackerman and Simmons 2016) and specifically in analyzing software solutions (Li et al. 2015). This author has



Software Development Processes Designed for First Year Computing Undergraduates, Fig. 6 Example of a CADET mind map. (Source: Author)

had experience of successfully using mind maps with inexperienced student developers.

The map will be refined into ordered tasks and subtasks. Abstraction will be used by the learner to articulate a trace backwards and forwards from the high-level summary from stage 1 into this stage to ensure consistency between the stages. Pattern recognition will be employed by learners to identify any tasks that have been utilized before in other problems (these will be marked with a pattern symbol). Finally, learners will continually evaluate their analysis of the problem and validate their proposed task list though tracing. They will make decisions about tasks that can be immediately converted into program code (color coded as green), require further design (color coded as orange), and those tasks of which they are unsure and which require assistance from their instructor (color coded red).

Design and Code

This stage employs the computational thinking skill of decomposition to take a task (colored

orange) and generate an algorithm represented as a flow chart for the task. This will also involve the skills of data representation and algorithm writing to represent the computational steps needed to represent a task solution as a flowchart with a level of detail to make it easy for the task to be converted into program code. Any task that has been color coded as green in the mind map can be programmed immediately with patterned tasks reusing or adapting existing designs. All tasks will be designed, coded, and evaluated in an iterative manner until correct and then reintegrated into a growing final product. Abstraction will be employed to ensure learners can oscillate between tasks identified in the mind map and any associated designs and code to trace their understanding at each functional and data abstraction level and ensure consistent mapping between stages.

Evaluate Solution and Learning

This final stage of the process allows the learner to reflect on their solution from start to finish and

employ abstraction to zoom in and out of their solution and understand it at the various functional and data abstraction levels and also be able to reconcile transition between those levels. Critiquing will be employed by the learners to see if any aspect of the solution could have benefited from using analysis, design, or coding artifacts from previous problems. Finally, the learner will be required to articulate what parts of the problem they were able to solve, what parts they either did not solve or found very difficult to solve, and what they need to learn or revise before moving on to the next problem. They should also be able to give a star knowledge rating to reflect the state of their knowledge in each of the computational thinking skills to help them reflect on their skill level.

When the process is being employed solely as a software development process, learners will be able to use both the process and associated tool by providing their own specification for a problem and then working through each of the above stages to systematically develop their final solution. This CADET process is currently being used and evaluated in this author's home institution.

Conclusion

Despite the recognized importance of software development processes both in software industry and in education, there is a need for more research into the provision of appropriate software development processes aimed at freshman, undergraduate computing learners in a context where learners predominately have little or no prior programming experience. The reason for the scarcity of such processes is due to the problematic nature of teaching software processes to novices. A software development process gives guidance to developers in the development of software solutions from analysis through to final product, but it is assumed that the developer has preexisting programming knowledge. This makes the use of such processes difficult for educators of introductory software development courses and produces a conundrum of how to support learners in the use of development processes in the absence of programming knowledge. In such an environment, it is natural that the focus of such courses will

gravitate towards the teaching of programming concepts first with the topic of development process coming later in the course or in later years. The problem with such a strategy is that it allows learners to potentially develop maladaptive cognitive practices which can prohibit learner progression in such courses.

This entry presents some of the most common development processes used in industry and in introductory third level education and makes the case that educational processes must take into account learners' varying degrees of prior programming experience. An educational development process is suggested which utilises the affordances of computational thinking to create a software development process that encompasses a learning process. The process combines current research into computational thinking as a problem-solving process underpinned by the focus of threshold concepts to support learners who are learning how to develop software solutions from problem specification through to the final tested product. The aim of the process is to provide scaffolding to learners as they learn how to develop software in a systematic fashion. This scaffolding will fade as learners become more experienced allowing them to continue to use the process as they grow their experience.

It is the contention of this research that the provision of such a process – while not a silver bullet to eradicate all of the problems learners experience in learning software development – would provide a structured and scaffolded environment to directly address the maladaptive cognitive habits that learners often form and find hard to unlearn. In any event, it is clear that more research into educational software development processes is needed in order to tackle proficiency and retention problems in undergraduate software development programs.

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Software Evolution

► **eXtreme Model-Driven Development (XMDD) Technologies as a Hands-On Approach to Software Development Without Coding**

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Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools

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Synonyms

[Computer and information literacy](#); [Mobile Learning](#); [New technologies](#); [Tablet computers](#); [Technology-related competences](#)

Introduction

The use of new technologies and the acquisition of technology-related competences have been widely considered relevant and even indispensable for participation in a modern knowledge and information society (Anderson 2008; Jordan et al. 2016). Recent developments have led to the emergence of new challenges for schools and school systems, resulting in an ever-growing need for students to develop new forms of relevant skills like digital literacy or computer and information literacy (Drossel et al. 2017). In view of the necessity to meet these challenges, tablet computers are seen as providing a variety of opportunities as mobile learning devices. International studies based on an increasing dissemination of tablet computers around the world have found tablet computers to have a positive effect at various levels of student learning. The effects include individual dimensions such as cognitive and metacognitive competencies (e.g., learning strategies and efficacy) as well as affective aspects such as motivation and also inter-individual collaboration and collegiality (cf. Li et al. 2010). With tablet computers combining the benefits of built-in cameras, microphones, and post-processing software for recorded media and multimedia working tools in one product, they also allow for the individualized installation of so-called applications in order to expand their range of functions at will (cf. Nguyen et al. 2007). Tablet computers are further considered to be advantageous due to their fast applicability, their direct and user-friendly handling, as well as their extended battery service life and resistance to system failures or manipulations (ibid.). With regard to their pedagogical use, tablet computers are assumed to improve students' individual advancement, enhance the flexibility of teaching and learning arrangements, establish collaborative working processes, and assist in comprehensively supporting students' media competence (cf. Enriquez 2010; Geer et al. 2017; Katzan 2015; Soffer and Yaron 2017; Woloshyn et al. 2017).

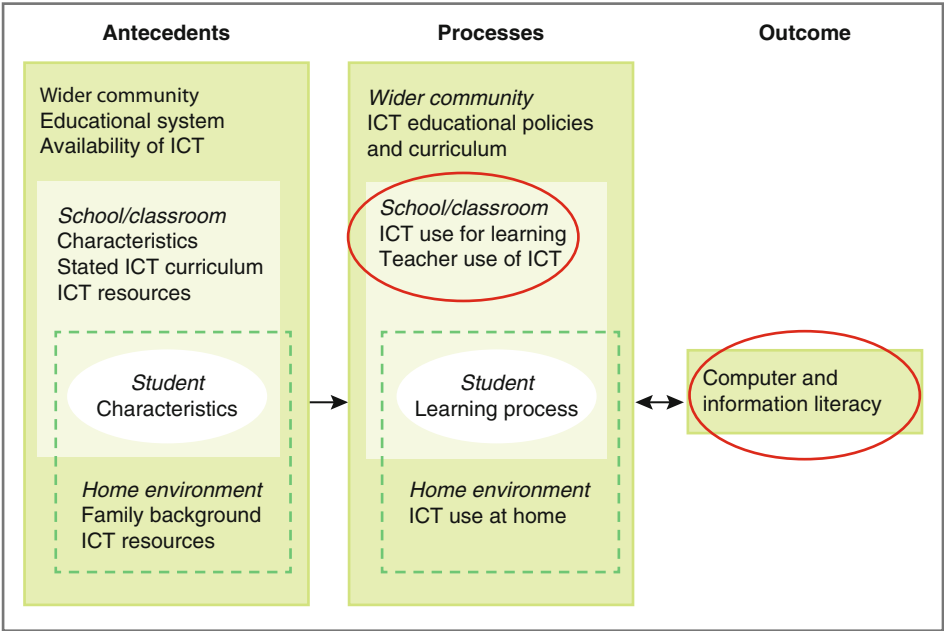
While research focusing on tablet computers for different educational purposes is increasingly common, the frequency of use by school subjects as well as the relationship between the use of tablet computers and skills such as digital literacy or

computer and information literacy has so far not been a key research interest. This research gap is elaborated on in this contribution using quantitative and qualitative data derived from the so-called TiGer project (2014–2017; the German acronym TiGer stands for “evaluating and reflecting use of tablet computers at upper secondary schools”) conducted at a German upper secondary school. This data set provides current in-depth data from a research project with a quasi-experimental longitudinal design. Referring to the abovementioned research gap, the aim of the study is to examine the extent to which the availability of tablet computers impacts their use in class, what level of computer literacy students have, and how this develops over time. In so doing, the overall issue of the role of tablet computers with regard to students' computer literacy is examined.

In the following, the central constructs, which are the basis for the tests applied to the students, are explained from a theoretical perspective. Furthermore, insights into the current state of research are presented and lead to the research questions addressed. Following a more detailed description of the design of the study, the research questions are answered and finally discussed on the basis of the findings of the study.

Theoretical Allocation of the TiGer Study

The relationship between the use of ICT (information and communication technology) and educational outcome is described in many theoretical models of school effectiveness (e.g., Biagi and Loi 2013; Law et al. 2008). One empirically elaborated model referring to computer literacy has been developed in the scope of the IEA (International Association for the Evaluation of Educational Achievement) study ICILS 2013 (International Computer and Information Literacy Study) focusing on to computer and information literacy (CIL) (Fraillon et al. 2013; see Fig. 1). With regard to the framework, the use of ICT is understood as a factor at the process level being part of a set of school and classroom factors. The model taken from the international study ICILS 2013 thus serves as a theoretical basis for the



Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools, Fig. 1 Theoretical model integrating computer literacy and students' use of computers in class (Fraillon et al. 2013, p. 26)

TiGer study; it integrated both students' outcomes and students' use of ICT.

Current State of Research: The Use of Tablet Computers and Computer Literacy

The current state of research will be presented bringing three strands of research together: Firstly, the use of ICT is presented by focusing on tablet computer use in schools and is examined by highlighting the situation in Germany within the international context. In a second step, insights into research with regard to students' computer literacy are provided, starting with a definition of computer literacy as it is understood in the scope of the presented research. The third and last strand brings together research findings on the relationship between computer use and students' achievement in computer literacy.

The Use of Tablet Computers at School and Conditions

Researching the use of mobile technologies in schools went through different phases, especially

when it came to laptop projects (e.g., Warschauer 2007). Research on tablet computer use in schools can be identified as a new wave of researching the use of mobile devices. Understanding schools and classrooms as multilevel systems, framework conditions of using ICT for teaching and learning have to be taken into account in order to understand the pedagogical use of such technologies. From a German perspective, it is particularly striking that in Germany, a traditional concept of IT infrastructure using static computers in computer rooms is still common practice (Fraillon et al. 2014). The use of mobile devices in schools in Germany is limited by the provision of IT infrastructure, and it can be considered distinctly below average in international comparisons and especially in comparison to Germany's neighboring countries (ibid.). According to the data gained from ICILS 2013, IT coordinators and school principals, a mere two fifths of students in Germany (43.7%) attend a school that provides a sufficient number of portable devices that can be carried from classroom to classroom. Close to one fifth of Grade 8 students in Germany (18.0%) report attending a school that follows a bring-your-own-device (BYOD) policy (as compared,

e.g., to 83.5% in Denmark). Furthermore, only 6.5% of upper secondary students reported that tablet computers were available for learning in school (ibid.).

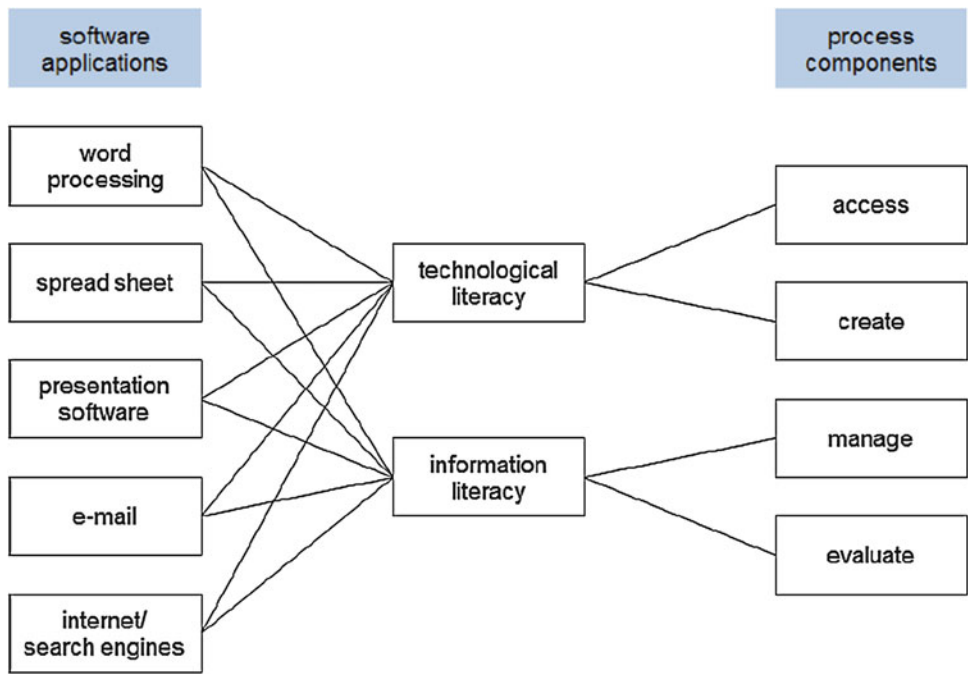
The international comparison in general further showed major differences not only in availability of ICT but also with regard to the use of computers at school. While 81% of students in Australia report using computers at least once a week, only 31% of students in Germany report doing so (Fraillon et al. 2014). Taking a closer look at subject-related use, i.e., the use of ICT in the test language subject (e.g., German for Germany), in mathematics and in foreign language subjects, it becomes evident that only three to 4% of students in Germany report regular (at least weekly) computer use in class. In international comparisons, Germany therefore comes last. Other countries such as Australia or Thailand report a significantly higher frequency of computer use in the abovementioned school subjects (ibid.). With regard to these and other findings, it becomes clear that studies including student achievement tests often do not differentiate between different technologies and their use in the classroom. With regard to the differences in applying the respective technologies – e.g., desktop computers compared to mobile devices – and taking different subjects into account, empirical data is scarce. A survey conducted in the USA on the use of tablets in class, however, assessed the use of tablet computers by school subject, differentiating between English, Math, History/Social Studies, Science, and Foreign Language classes (Pearson 2013). The results show that around half of students in elementary school, middle school, and high school use full-size tablets in class several times a week (ibid.). The findings further indicate significantly higher proportions of tablet use in middle schools, i.e., among students up until Grade 9, with the exception of English classes (ibid.). While the results are available from the 2013 Student Mobile Device Survey, the follow-up studies from 2014 and 2015 no longer include data on the frequency of tablet use by school subject, thus not allowing for a longitudinal comparison. Furthermore, the scope of the data is limited to the US-American educational

landscape, thus not allowing for international comparisons.

Students' Achievement in Computer Literacy

Prior to summarizing relevant findings regarding students' computer literacy, the understanding of computer literacy in this contribution needs to be further clarified. Against the background of the instruments used in the TiGer study, computer literacy is defined from a functional perspective. This functional perspective emphasizes the relevance of including "the knowledge and skills that people need to live satisfying lives, in terms of personal and economic satisfaction, in modern-day societies" (Senkbeil et al. 2013, p. 142). Computer literacy is conceptualized as a unidimensional construct comprising the facets of technological and information literacy (ibid.). The construct is therefore also known as technical and information literacy (Senkbeil and Ihme 2012). The information component is defined as the ability to recognize when information is needed and the ability to locate, evaluate, and use the needed information effectively. The technological component means the underlying knowledge of hardware, software applications, networks, and elements of digital technology (ibid.). Additionally, computer literacy differentiates between software applications (e.g., word processing) and process components (e.g., access) (cf. Fig. 2). Based on these insights, computer literacy can be assumed to be applicable to the use of tablets in teaching and learning processes as tablet computers are considered mobile computing devices. The differentiation between technological and information literacy, which both form part of the aforementioned construct of computer literacy, is also valid for tablet computers.

In efforts aimed at assessing students' achievement in computer literacy in an international context, studies around the world have investigated ICT-related competencies of students based on different understandings of computer literacy examined using a variety of methods. Hakkarainen et al. (2000) in Finland, for instance, used a design that relies on the students' self-reported competencies. While the students performed quite well in mastered text processing,



Students’ Computer Literacy and the Use of Tablets in Upper Secondary Schools, Fig. 2 Assessment framework for computer literacy (process components and software applications) (Senkbeil and Ihme 2012, p. 5)

graphical processing, information networks, and file management, they were not as proficient in authoring tools, desktop publishing, programming, and computer hardware. For Chilean students, Claro and colleagues (Claro et al. 2012) used a performance-based assessment design – the ICTSfL test. The results merely show that the students’ skills related to the use of ICT as consumers exceeded the level of skills related to becoming producers using ICT (ibid.). While the aforementioned studies tend to focus more on the data gathered, other studies from Australia have been used to develop an overall ICT literacy scale using computer-based achievement tests, from which proficiency levels regarding computer literacy have been deduced (cf. ACARA 2012; MCEECDYA 2010). While the Australian studies and all studies mentioned above display a scope limited to a region or country, international comparisons of computer literacy in students were, for the very first time, examined in the context of IEA study ICILS 2013. As a result, students’ achievement in what is described as computer and information literacy in the study showed a great

variation between the participating countries. Grade 8 students in Germany reached an average performance of 523 scale points, statistically not significantly different from the European average (525 scale points for EU countries) but significantly above the OECD average (516 scale points) and the international average of 500 scale points (Fraillon et al. 2014). This finding prompts the question as to where students acquire their competences and in which way the use of ICT in schools can support students’ achievement, including the issue of which particular technologies best meet pedagogical needs and support the acquisition of computer literacy.

The Relationship Between the Use of New Technologies and Computer Literacy
Closer investigation reveals that the role of new technologies in classrooms and their impact on students’ performance have been the focus of research literature over the last two decades (cf. Spiezia 2010). Cox and Marshall (2007) have pointed to the fact that a multitude of factors influences both students’ use of ICT and their

ICT-related skills. The authors mentioned factors such as the quality and depth of ICT use, the observations of students using ICT, and the analysis of students' products. Furthermore, meta-analyses (Li and Ma 2010; Tamim et al. 2011) suggest that there is a positive relationship between ICT use and student achievement in different subject areas. While ICT has been examined with respect to its influence on subject-related achievement such as in mathematics and science, the use of new technologies and its relationship with computer literacy has thus far been investigated to a much lesser extent. Only very recently, Rohatgi et al. (2016) were able to show based on data gathered in Norway that the use of ICT has an indirect impact on the computer literacy of students, the intermediate construct being ICT self-efficacy. Sung et al. (2016) in their meta-analysis have further found mobile devices to be more effective than desktop computers or laptops when it comes to students' learning performance. Focusing again on direct effects, the research interest of this contribution comprises both teachers' and students' use of the aforementioned technologies. As far as teachers' use of computers is concerned, international comparisons show a positive effect on CIL in Germany only, contrarily to Australia, Norway, and the Czech Republic (Gerick et al. 2017). Regarding school-related use of computers by students, international comparisons revealed consistently positive relations. Warschauer (2007), for instance, was able to demonstrate that students attending notebook schools (including primary and secondary schools) learn to access, process, and use information much better while also acquiring skills to integrate this information into written and multimedia presentations. Likewise, an Australian study conducted by the National Assessment Program ICT Literacy pointed out that the school-related use of computers shows a positive correlation with students' ICT literacy competencies (MCEECDYA 2010). The ICILS 2013 international comparison also demonstrated that school-related computer use in most participating countries correlates positively with CIL. Only three countries, including Germany, showed a negative effect (Eickelmann et al. 2014). While some authors regard the

literacy developed through the use of tablet computers to be a new, distinct literacy known as tablet computer literacy (cf. Hergüner 2016), the relationship between school-related use of tablet computers and computer literacy has thus far not been addressed. A meta-analysis of 23 tablet-related studies by Haßler et al. (2015) revealed that while the majority of research reports positive effects of tablet use on student learning outcomes, other research, however, indicates that tablet use may indeed have no effect or may even have negative consequences. The authors conclude that "the fragmented nature of the current knowledge base, and the scarcity of rigorous studies, make it difficult to draw firm conclusions." In-depth investigations are advised (ibid.). Accordingly, Kontkanen et al. (2017) conclude that "[t]he value that iPads add to teaching and learning is difficult to quantify because of the complex and often conflicting factors involved" (p. 1299).

Research Questions

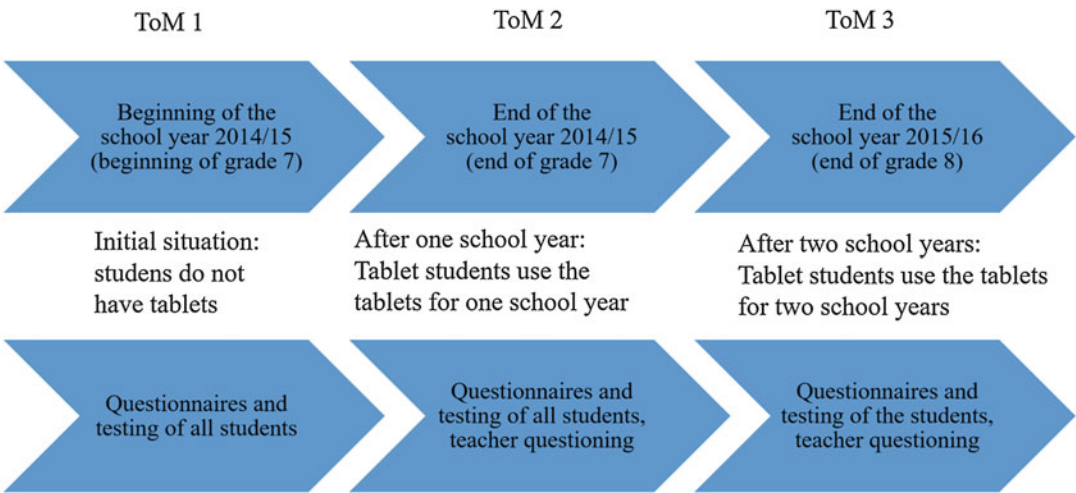
The following research questions can be deduced from the research desiderata described above:

- (I) How often do students use tablets in school? Is there a difference between students in tablet classes and in regular classes?
- (II) What level of computer literacy do students have at their disposal? Is there a difference between students in tablet classes and regular classes?
- (III) Which role does the use of tablets play in this context? Is there a relationship between the use of tablets and computer literacy?
- (IV) To what extent do teachers notice any developments regarding tablet class students' computer literacy?

Methodology

Sample

In order to answer the above research questions, this entry uses the data provided by the TiGer project (*evaluating and reflecting tablet*



Students’ Computer Literacy and the Use of Tablets in Upper Secondary Schools, Fig. 3 Design of the TiGer project

computers at upper secondary schools). This project used expert guidance in the process of introducing tablet computers to Grade 7 students at an upper secondary school (*Gymnasium*) in Germany. Tablet computers were used from the beginning of the 2014/2015 school year. These mobile devices are owned by the students who could therefore also use them outside school. Two out of five parallel classes were fully equipped with tablet computers, while the remaining three classes continued without tablets, hence serving as control groups. The concomitant research involves an elaborate triangulation design of multiple perspectives over a period of 2 years. The focus of this research contribution is placed on a quantitative student survey with three points of measurement. The first data was generated at the beginning of the 2014/2015 school year when the students were not yet in possession of any tablet computers (pretest; Time of Measurement 1; ToM 1). The second data was collected at the end of the 2014/2015 school year, with tablet class students having worked with tablet computers while students from the control group had not (Time of Measurement 2; ToM 2). At the end of 2015/2016 following another school year, the students were tested again (Time of Measurement 3; ToM 3). The project thus offers data from three measurement time points over a period of 2 years (see

Fig. 3). In order to model the longitudinal section, all students who had not participated at all three measurement points were excluded from the analyses. The original 119 participants were hence reduced to 105 students that constitute the sample. 43 of these were taught in tablet classes, whereas the remaining 62 attended parallel classes in which no tablet computers were used and that can hence serve as a control group. Furthermore, the quantitative data is subsequently complemented by qualitative teacher data, which was gathered in the form of open-ended questions in teacher questionnaires (at ToM 2 and ToM 3).

Instruments and Methods

In the following, the instruments (tablet computer use and computer literacy) used in the study will be presented in more detail. Furthermore, the methodological approach will be described and an account given of the need for the complex design of a longitudinal quasi-experimental study design incorporating qualitative and quantitative data.

The use of tablets was assessed in a subject-specific approach for all school subjects. In the following, frequency of tablet use is reported for the main subjects – German, Mathematics, and English. The students’ fourth main subject (French or Latin) was excluded from the analyses

Students’ Computer Literacy and the Use of Tablets in Upper Secondary Schools, Table 1 Results of the exploratory factor analysis of tablet use (German, Mathematics, and English)

	ToM 1		ToM 2		ToM 3	
	Tablet classes	Control group	Tablet classes	Control group	Tablet classes	Control group
<i>N</i>	33	43	41	54	40	53
Cronbach’s alpha	0.968	0.840	0.855	0.832	0.547	0.646
Explained variance	94.6%	77.3%	80.3%	75.3%	55.6%	59.0%

because students from tablet classes and students forming part of the control group were taught together. These particular classes therefore did not use any tablet computers. The four-tier response format ranged from *never* (1) to *every week* (4). The use of tablet computers is regarded both subject-specifically and as a latent construct used for further analyses. The exploratory factor analysis of subject-specific tablet use, which only includes cases in which data for at least two subjects was available, reveals that the three selected items show factor loadings on one factor with a very good reliability for both groups of students at all measurement points (cf. Table 1). The question as to whether significant differences can be detected between the groups will be tested using a significance test for independent samples.

For the purpose of assessing students’ computer literacy, the understanding of computer literacy explained above seems to be appropriate. The tests referring to this concept derive from the National Educational Panel Study (NEPS) in which a computer literacy test for students in different grades was developed (Senkbeil and Ihme 2012). Due to the fact that certain tasks covered by the NEPS test were no longer up to date at the time of measurement – which can be attributed to the fast-paced development of new technologies – these tasks were replaced by corresponding items. Examples of items measuring the different aspects of computer literacy can be found in Senkbeil et al. (2013). As part of this test, the multiple choice items cover both the software application and the process components shown in Fig. 2. The paper-pencil test consisting of 36 tasks (including 30 simple multiple choice and 6 complex multiple choice items) depicts real-

life problems embedded in a range of authentic situations using screenshots.

In order to estimate item and person parameters for computer literacy, a partial credit model was used and estimated in ConQuest (Wu et al. 1997). In a first step, ability estimates were estimated as weighted maximum likelihood estimates (WLEs, Warm 1989) with a metric of 500 and an SE of 100. As the same computer literacy tests were used at all measurement points, the item parameters of ToM 1 are implemented to estimate the item difficulty of ToM 2 and ToM 3. The results show that the items exhibited good item fit. Furthermore, the test showed high reliability for the three measurement points (0.974/0.971/0.972), and the different comprehension requirements support a unidimensional construct. In addition to measuring the students’ competencies, open, qualitative questionnaires were distributed to the teachers responsible for teaching the tablet classes (*N* = 6). This complementary instrument results in a multi-perspective, triangulative design of the study, which is expected to contribute to the second research question addressed by this paper.

Findings

Findings on the Use of Tablet Computers

At the beginning of the school year (ToM 1), neither the students in tablet classes nor the students in the control group used tablet computers in their main subjects (cf. Table 2). The two groups therefore do not show any significant differences. It can hence be established that the starting situation is the same for all students. At ToM 2, after 1 year, as well as at ToM 3, after 2 years, the

Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools, Table 2 Students' tablet use differentiated by tablet class and control group at ToM 1, ToM 2, and ToM 3

ToM1							
Tablet classes				Control group			Sig
	N	M ^a	SD	N	M ^a	SD	p ^b
German	35	1.2	0.62	46	1.2	0.59	ns
English	35	1.1	0.55	48	1.4	0.89	ns
Mathematics	35	1.1	0.55	46	1.2	0.56	ns
Main subjects total	35	1.1	0.55	48	1.2	0.61	ns
ToM2							
Tablet classes				Control group			Sig
	N	M ^a	SD	N	M ^a	SD	p
German	41	3.9	0.53	54	1.2	0.54	0.000
English	41	3.9	0.55	55	1.3	0.73	0.000
Mathematics	41	3.8	0.71	55	1.2	0.57	0.000
Main subjects total	41	3.8	0.53	55	1.2	0.53	0.000
ToM3							
Tablet classes				Control group			Sig
	N	M ^a	SD	N	M ^a	SD	p
German	42	3.7	0.63	54	1.6	1.04	0.000
English	40	3.7	0.64	53	1.2	0.59	0.000
Mathematics	42	3.8	0.65	54	1.6	1.08	0.000
Main subjects total	42	3.8	0.46	54	1.5	0.71	0.000

^a1, never; 2, less than once a month; 3, at least once a month but not every week; 4, at least once a week

^bns, not significant

Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools, Table 3 Students' performance indexes (WLE) in computer literacy differentiated by tablet classes and control group at ToM 1, ToM 2, and ToM 3

Tablet classes		Control group		Sig
M	SD	M	SD	p
ToM 1				
472.9	102.8	520.7	93.54	0.021
ToM 2				
473.3	108.0	520.4	89.1	0.021
ToM 3				
448.0	97.5	539.7	82.76	0.000

results show that tablet class students use tablet computers at least once a week. No significant differences between the main subjects could be observed. As expected, the control group does not show any changes with respect to the first measurement time – the use of tablet computers can still be considered an exception here. The differences between students from tablet classes and students from the control group were all found to be significant.

Findings on Students Computer Literacy

The level of computer literacy that students have at their disposal as well as the extent to which students from the tablet classes and from the control group show differences in terms of their performance will be presented in the following and is shown in detail in Table 3. In order to describe students' achievement, the achievement indexes (WLEs), which were previously transformed to a mean score of 500 with a standard

deviation of 100, are reported with a view to enabling better interpretation of the results. The correlation of the WLEs amounts to 0.685 for the tablet classes and 0.678 for the control group. This suggests that the computer literacy construct remains relatively stable over time.

The average achievement of the students taught in tablet classes before obtaining the devices lies at 472.9 scale points, thereby displaying significantly lower scores in comparison with their fellow students from the control group (520.7 scale points). This result remains in force even after the introduction of tablet computers and repeated computer literacy measurement procedures after the school year. Both the control group and the tablet students attain – on average – the same level of competencies as they did at ToM 1, resulting in the fact that tablet students yet again show a significantly lower average level of achievement regarding computer literacy. However, 2 years after the introduction of tablets in the two tablet classes, changes in performance are apparent although they are different from those expected. On the one hand, the tablet students perform significantly less well than in the 2 preceding years (448.0 scale points). On the other hand, the students in the control group perform significantly higher (539.7 scale points).

Relationship Between Computer Use and Computer Literacy: Students’ Achievement

As explained by means of the theoretical framework model (cf. Fig. 1), a correlation between the use of tablet computers and computer literacy can be assumed. At ToM 1, this correlation is not significant for the tablet classes (at 0.209) but proves to be significant for the control group (at 0.389 with $p = 0.005$). The second measurement time shows a substantially smaller correlation that is not significant in either case (–0.011 for tablet classes; 0.183 for the control group) (cf. Table 4), while by ToM 3, the correlation in the tablet classes increased (0.466 with $p = 0.002$), and the (not significant) correlation in the control group became much lower (–0.043). Overall, the assumed correlation between the use of tablet computers and computer literacy can only be

Students’ Computer Literacy and the Use of Tablets in Upper Secondary Schools, Table 4 Correlations between the use of tablet computers and computer literacy differentiated by tablet classes and control group at ToM 1, ToM 2, and ToM 3

Tablet classes		Control group	
r	p	r	p
ToM 1			
0.209	ns	0.389	0.006
ToM 2			
–0.003	ns	0.200	ns
ToM 3			
0.466	0.002	–0.043	ns

detected for ToM 1 for the control group and for ToM 3 for the tablet classes.

Relationship Between Tablet Computer Use and Computer Literacy: Teachers’ Perspectives

In contrast to the findings from this performance test, the teachers’ impressions as reflected by the qualitative data gathered from an open questionnaire do indicate an improvement in students’ computer literacy. One teacher, for instance, found that “the students use the tablet more like a tool while the ‘play instinct’ gradually decreases. The exhausting of all of the tablets’ functions is impressive. Information research, the preparing of presentations, drafting of emails and saving documents in clouds has become routine for most [students]. The targeted use of apps also becomes more and more conscious” (Mrs Schmidt, 35 years old, teacher of Arts and Spanish). This reflects the experience of all six teachers, especially with regard to the more confident and conscious use of the new technologies. Individual teachers, however, also point to “alarming” cases, where “girls lacking in confidence” continue to have difficulties using basic applications after 1.5 years of using the tablet computers.

Conclusion

The main focus of this paper was to investigate whether the use of tablet computers in the scope of

a 1:1 setting has effects on students' learning and especially on students' computer literacy. An analysis was performed based on qualitative and quantitative data from a tablet project carried out in an upper secondary school. In this project, two out of five parallel classes (starting in Grade 7) were fully equipped with tablet computers, while the remaining three classes continued without tablets, hence serving as control groups. Data was gathered at three points in time over a period of 2 years, starting with data collection immediately before the tablet computers were distributed to the students.

First of all, the analyses have shown that in line with expectations, the tablets were used on a regular basis in the main subjects after their introduction. Students in tablet classes subsequently used tablet computers on an at least a weekly basis, while the frequency of tablet use in the parallel classes without tablets did not change over time and still corresponds essentially to the category of "never." Hence, it is not surprising that students in tablet classes use tablets in class significantly more often than the students in the control group. This result primarily emphasizes the importance of material resources available to students that constitutes a prerequisite for the implementation of new technologies (Eickelmann et al. 2014).

With regard to the second research question, it can be stated that average computer literacy – as tested using the TILT test – was substantially lower among tablet students than among students from the control group both prior to and following introduction of tablet computers. One year after the introduction of the tablets, there were no changes in levels of computer literacy, and after 2 years, it became apparent that tablet students were achieving lower levels, while the control group was improving. These findings were not to be expected; however, they do appear rather plausible when taking a closer look at the instrument with which computer literacy was tested and its theoretical conception (cf. Fig. 2). Contrary to the findings from this performance test, the teachers' impressions as reflected by the qualitative data gathered from an open questionnaire do point to an improvement in the students' computer literacy. This result shows how

important it is to include the teacher's perspective (see also Eickelmann and Vennemann 2017). According to preliminary findings (teacher, student, and principal perceptions), the software applications used there did not correspond to those that were put to use by the tablet classes. For instance, students did not send emails using their tablets but communicated via specially designed communication applications. Further differences were found with respect to the process components of the theoretical framework model of computer literacy. The way in which tablet students manage information, for example, is completely different from the way it is operationalized in the TILT test. The students used the tablets' cameras to digitalize and save documents – a competency that is not assessed by the instrument. It is, however, worth noting that for the German-speaking world, there is currently no valid and openly accessible instrument available to account for these diverse potential applications that are unique to tablet computers. With development in this area being rather fast-paced – both with respect to software applications and hardware – the designing of a suitable and valid instrument indeed constitutes a major challenge. A further possible explanation for the persisting difference in the level of computer literacy could lie in the fact that students from the control group acquired their skills outside of the classroom. This remains to be verified and could constitute the focus of further analyses.

A third result of this research contribution reveals that the assumed correlation between the use of tablet computers and computer literacy as depicted by the theoretical framework model (cf. Fig. 1) cannot be maintained. The same is true if these results are compared to multiple research findings that have asserted a direct relationship between the two constructs (Li and Ma 2010; Rohatgi et al. 2016; Sung et al. 2016; Tamim et al. 2011). At first glance, this result therefore seems unexpected, while it does support the assumption that the TILT instrument could not measure the competencies as they were acquired by students through the use of tablet computers.

From the teacher interviews (question 4), it becomes apparent that there are indeed positive

effects that result from the use of tablet computers, namely, an increase in motivation and confidence in regard to the conscious and targeted use of new technologies.

While the study documented in this entry only can serve as a starting point – data from the study is not representative either for Germany nor for the focused school form – studies with representative samples (e.g., large-scale assessments) may elaborate on the findings presented in the scope of the TiGer project.

Cross-References

- [Computers in Secondary Schools](#)
- [Implementation of ICT in Secondary Schools](#)
- [Mobile Computing and Mobile Learning](#)
- [Mobile Learning](#)
- [Tablet use in Higher Education](#)

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Success Factors

► [Learning Programming, Success Factors](#)

Summative Assessment

► [Information Technology and Assessment](#)

Support for School and Institutional Improvement and Accountability

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Synonyms

[Accountability](#); [Institutional improvement](#); [Institutional leadership](#); [Instructional leadership](#); [School improvement](#); [School leadership](#)

Definition

Support for school and institutional improvement refers to the suggestions and guidelines for institutional leaders to be instructional leaders who are accountable for improving instructional practice and developing human capacity. An instructional leader inspires the institution in achieving a shared vision, develops policies related to the vision, builds a culture of data for decision-making, develops instructors' capacities in technology and pedagogy, and provides the technology infrastructure and strategies for community involvement.

Students' Performance

► [Information Technology and Assessment](#)

Introduction

Administrators, either as heads of schools or managers and governors of higher education institutes, have a prominent leadership role. They influence the condition of their staff's work life, which can in turn influence staff effectiveness and students' achievement outcomes (OECD 2009; Pont et al. 2008). However, technological innovation and recent changes in migration and globalization have changed the expectations of students and their parents and posed challenges to administrators (OECD 2009). Globalization and widespread immigration has resulted in a demand for quality education across national boundaries (MacBeath 2009). Students are holding the institutions and their leaders accountable for improving their performance and demand quality education (MacBeath 2009).

The shift toward new pedagogies for learning with technology and reforms in curriculum, assessment, governance, and financing has begun in education systems in many countries. Educational systems need to be transformed for youth to be equipped with knowledge and skills needed in the changing world (OECD 2009). Hence, the role of the institutional leader also needs to change.

Students today are natives of the imagination age: they use virtual reality and innovative technologies for recreational gaming and communication (King 2016). They demand to be equipped with future skills for future jobs. Skills of creativity and innovation need to be developed among students, and this means more demanding educational programs should be implemented in educational institutions, thus, pressuring administrators to produce excellent students from the system. Parents and other stakeholders have higher expectations and accountability from the institutional leaders on students' performance and return on investment in the school system.

However, our institutional leaders may not be equipped to deal with developing skills for solving problems of the future in the imagination age (King 2016). Most institutional leaders were trained in methodologies suitable for the industrial

age, which are irrelevant for knowledge workers and natives of the imagination age (King 2016; Pont et al. 2008). Hence, some suggestions for supporting institutional leaders to be accountable to their stakeholders are made by developing instructional leadership and inspiring the institution to achieve a shared vision, to develop policies related to the vision, to build a culture of data for decision-making, to develop instructors' capacities in technology and pedagogy, and to provide the technology infrastructure and strategies for community involvement.

Accountability

Institutional leaders are held accountable for their institutions' achievements. Governments and other stakeholders who have invested in education systems require these institutions to be accountable for the monetary input provided. Students also demand a quality education relevant to their future employability for the tuition fees they paid. These demands for accountability is believed to motivate institutions toward quality improvement and attaining high standards (Geijsel et al. 2010). Hence, institutional leaders exercise their leadership by implementing systems of observation, monitoring, appraisal, benchmarking, and targets for accountability within their institutions (MacBeath 2009).

Accountability can take many forms. Accountability to external organizations and other stakeholders requires traditional reporting systems, while internal accountability involves a self-inspection of the organization for continuous improvement (MacBeath 2009). Traditional systems of public accountability, such as elections, can hold central governments accountable for education policy failures (Hooge et al. 2012). However, as institutions are given more autonomy, these traditional systems may not work. Different systems of accountability are needed.

The purpose of accountability should be more than just for the attainment of skills and knowledge. Geijsel et al. (2010) outlines three purposes of accountability: the legitimation of the institution in compliance with laws and regulations;

accounting for the quality of services related to the education provided (effectiveness), value for money (efficiency), equity, or access; and finally for the overall improvement of education (Hooge et al. 2012). Hence, measures of accountability should include effectiveness, efficiency, equity, and access to education, rather than only school or institutional performance.

Types of Accountability

Presently, there seems to be two types of accountability mechanisms practiced. Vertical accountability is a hierarchical concept concerned with enforcement of compliance with laws and regulation. Vertical accountability for school performance uses standardized student testing and public reporting of school performance using measures of student information and characteristics, safety issues, curriculum, facilities and grounds, and teacher qualification (Hooge et al. 2012). This form of performance accountability may neglect measures of essential elements and may compromise the teaching and learning processes when instructors reduce the scope of the curriculum and “teach for the test.” As an example, the majority of OECD countries uses a standardized test as an objective measure of skills and knowledge for school performance accountability (Hooge et al. 2012). The results of the testing are used to monitor and ensure the quality of education. However, this standardized test neglects other important goals of education such as development of social skills, moral values, creativity, and other skills for employability (Hooge et al. 2012; MacBeath 2009).

Horizontal accountability, on the other hand, is nonhierarchical and directed at the processes in which institutions and instructors conduct their professional practice with involvement of multiple stakeholders in the educational processes of decision-making, implementation, and verifying results (Hooge et al. 2012). Denmark, the Netherlands, and the United Kingdom make use of multiple school accountability. Students, parents, communities, and other stakeholders are involved in formulating strategies, decision-making, and evaluation for education for improving of the quality of schools (Hooge et al. 2012).

This multiple accountability seems to reduce the negative effects of school performance accountability and makes schools accountable to students, their parents, members of the community, and the community as a whole (Hooge et al. 2012). Hence, multiple aspects of schooling are taken into account from various information sources. There is now a shared responsibility among students, their parents, members of the community, and the community as a whole, to ensure that the school system is effective and continuously provides quality services.

Technology has enabled data collection and analysis for accountability, to be more efficient. Both vertical and horizontal accountability can be reported when data for accountability is systematically collected. This data, when analyzed for meaningful connections, can be effective in identifying problem areas, strengths of programs conducted, as well as the strengths and weaknesses in students’ knowledge and skills (Tolley and Shulruf 2009). The institutional leader can then employ data-driven decision-making to maximize planning for accountability (Tolley and Shulruf 2009).

Instructional Leadership for School and Institutional Improvement

Research has shown that the primary factor for effective schools and institutions is the professionalism of the leadership. There seems to be a correlation between instructional leadership and students’ academic performance, as well as teachers’ effective instruction (Heaven and Bourne 2016; Leithwood and Riehl 2003).

When some of the models of effective leaders are reviewed, it is shown that the behaviors of heads of institutions, which are establishing a clear focus and high expectations on student learning, providing instructional leadership, supporting teacher autonomy, and developing a conducive culture, have an impact on students’ achievements (Cotton 2003).

By setting directions, having a shared understanding of organization and a sense of identity, as well as monitoring the organization’s

Support for School and Institutional Improvement and Accountability, Table 1 Summary of instructional leadership models

	Cotton (2003)	Leithwood et al. (2004)	Jones et al. (2009)
Inspiring a Vision	Clear vision, goals, and high expectations	Setting directions, shared understanding of organization, its activities and goals	Vision/mission/goals Personnel and budgets Policies and procedures Staff reviews and evaluations Student achievement data analysis
Data for decision-making		Monitoring	Staff reviews and evaluations Student achievement data analysis
Instructional leadership	Observing classroom teaching and feedback Protect instructional time	Offering intellectual stimulation Providing individualized support	Academic intervention Coteaching/team teaching Balanced assessments Classroom walk-throughs Grading Peer review of student work
Capacity building		Providing appropriate models of best practice Beliefs considered fundamental to the organization Capacities and motivations	Individualized professional learning Instructional coaching Mentoring Instructional technology Professional development workshops Teacher observations/study tours
Community's involvement	Shared leadership and decision-making Support teacher autonomy Risk taking for continuous improvement	Distributed leadership: shared, collaborative, democratic, and participative Organizational conditions Extrinsic financial incentives or intrinsic commitment to the welfare of students	Leadership teams Needs assessment/strategic planning Rigor/relevance framework Teacher incentives and rewards Professional learning community

performance and effective communication, a shared, collaborative, and participative leadership is developed (Leithwood et al. 2004). This shared, collaborative, and participative concept of leadership can contribute to the organization's success (Leithwood et al. 2004). The instructional leader who provides intellectual stimulation, with individualized and organizational support, shares models of best practices, and develops capacities and motivates teachers would be more successful (Leithwood et al. 2004).

Instructional leadership would mean having a common vision of good instruction, an emphasis on building relationships, and empowering staff to innovate, provide feedback, and share best practices (Jones et al. 2009; Heaven and Bourne 2016). Jones et al. (2009) also provided a framework of instructional leadership by outlining the practices of instructional leaders.

The review of several established models of effective leaders showed that the important aspects are to inspire a vision, set policies, establish the vision, build capacity building, and involve the community (see Table 1). Monitoring and continuous evaluation through systematic data collection ensures that the standards of the organization are maintained. The instructional leader models the way that teaching should be conducted, and provides capacity building by mobilizing a dedicated team, provides guidance in improving instructional practices, and involves the community at large.

The models of instructional leadership are applicable for both schools and higher education institutions and can be used for implementing a technological innovation such as e-learning. Hence, for this purpose, the leaders of the school and higher educational institutions will be referred to as the *instructional leader*.

Inspiring a Shared Vision

The institutional leader sets the direction for the institution. A shared understanding among colleagues about the organization, its activities, and its goals is required for a sense of identity (Leithwood et al. 2004). Goals which are personally compelling, challenging, and yet achievable are more likely to develop a sense of identity for the project within their work context goals (Leithwood et al. 2004). However, developing a shared vision for a new innovation, example an e-learning initiative, is not a simple task.

The purpose of an innovation is to bring about better outcomes. Hence, it is still very important for the leader to have a vision of the better future to be shared among his colleagues. However, in developing this vision, it is important to be aware of opportunities and emerging future trends, and not be limited to present successes in the implementation of the innovation. Instead, the targets set should not be based on present-day achievements because technology is constantly changing and constantly moving targets (Cavanagh and Thompson 2018).

Developing a Vision

Cavanagh and Thompson (2018) suggest the leader needs to have a strategic and rewarding vision of the future by considering several aspects. The leader needs to be informed of four situations as follows:

- (a) *Here/Now*: The operations in the current situation.
- (b) *There/Now*: An understanding of the successful implementation of technology in other similar institutions in the current situation. This is obtained through collegial exchange and consultations through teleconferences, site visits, and conferences.
- (c) *There/Then*: Global context and trend forecasting. The distant vision which is based on a global long-term perspective at a distance from the immediate context. The New Media Consortium's Horizon Report is published annually for K–12 schools and for higher education and identifies key trends and important

developments in educational technology which can provide the vision for the future (see <http://www.nmc.org/nmc-horizon>).

- (d) *Here/Then*: Leaders should envision how things will be or should be in the local context from the *There/Now* and *There/Then* contexts and implement strategic planning in order to achieve the vision. Strategic planning for technology for learning should be in line with the institution's strategic plan and should also take into account innovativeness.

The successful development of a shared vision considers the current technology in other situations and places, the emerging trends and technologies for the near future, and the vision of senior leaders for the institution in the future (Cavanagh and Thompson 2018). In other words, a leader should constantly be monitoring trends, studying the applicability of a valued outcome in the context of his institution, and evaluating the possibility of successful implementation in his institution by "reading the sign of the times" (Cavanagh and Thompson 2018).

Policies

Policies assist the institution in planning and mobilizing the action needed for implementation of an innovation. Czerniewicz and Brown (2009) define policy as both the formal documentation and the course of action to be taken, which encompasses the allocation of goals, values, and resources. Hence, the intentions of the policy documents must be taken with an examination of existing systems, services, and structures. Czerniewicz and Brown (2009) also differentiate between having a *structured* and *unstructured* institutional policy. A structured institutional policy would have formal support from senior level management as a formal policy document exists, with structures to support the reform policy, such as a support unit for the institution, and a system for the institution (Czerniewicz and Brown 2009). On the other hand, an unstructured policy does not have any documentation nor support systems in place. Support given may be on the individual

basis and at the convenience of the technical support staff.

Some studies show that having an institutional policy expresses the commitment of the senior leadership to the change in the organization (Czerniewicz and Brown 2009; Nichols 2008). When there is no structured policy, staff will be constrained in the implementation of the innovation due to lack of support and vision (Czerniewicz and Brown 2009). Hence, although a policy may not be the force that moves the change, having a policy can ensure that the operations and activities related to the innovation are implemented (Czerniewicz and Brown 2009). Some examples of policies required are discussed next.

Information Policies

Information policies are specifically those “laws, rules, regulations, and guidelines, both formal and informal, that affect the way individuals and organizations collect, create, access, retrieve, disseminate, transform, curate, preserve, and destroy information” (Walster 2018, p. 143). In implementing e-learning, policies are required in all aspects of the e-learning environment such as privacy and security of personal information, creation and use of intellectual property, and guidelines on the use of copyrighted materials.

Walster (2018) suggests some information policies that should be documented:

1. *Policies regarding the privacy and security of personal information.* In most countries, the rights of the student until he is 18 years remain with the parents. For example, the US Department of Education, the Family Educational Rights and Privacy Act (FERPA) which protects the privacy of students’ educational information, may be applied differently at K–12 education and after secondary school. The institutional leader needs to be aware of this act and how it affects students.
2. *Policies regarding proprietary information which cannot or should not be shared.* Materials on the Learning management systems have different policies and distribution or access rights which might limit the access

to the resources or software. Variation in these policies needs to be made known to the users.

3. *Policies regarding information storage, backup, and destruction.* The systems, networks, servers, and storage facilities on where information can be stored and searched, as well as the back-up schedules if related, need to be made known and coordinated.

Examples of Information Policies by Function

Information policies may be categorized by function as they may affect administration, instruction, and learners. Walster (2018) provides some examples:

1. *Information policies which impact administration of e-learning environments.* Information policies which originate at the government level may influence the overall functioning of e-learning initiatives. Personal information privacy and security is affected by government’s central policies (e.g., FERPA), and this would translate to the learning management systems (LMS) privacy and security policies regarding personal information. However, information policy requirements for government and corporate sectors might be different. Corporate entities are under no such obligation to have information policies related to privacy.
2. *Information policies which influence the design and delivery of instruction.* Information policies on copyright guidelines, intellectual freedom, academic freedom, and library policies can impact the design and development of materials for e-learning. Issues which may arise are proprietary systems restrictions, user registrations, password protections, as well as privacy and security of personal information.
3. *Information policies which affect learners.* Learners have no choice in the selection of learning management systems, the way information policies are implemented, or how information policy is written for their organization. However, they should be made aware of their rights and responsibilities. This may mean that an organization needs to write information policies or procedures to inform

students of those policies which will affect their privacy and security, as well as on intellectual property, communication, access, and retrieval of data.

In conclusion, for improving the information policy environment, one needs to firstly, make an inventory of existing information policies in the organization. Next, evaluate the quality, consistency, and coherence of the information policies affecting e-learning. Finally, improve the information policies by making it current, while continuously revising, and coordinating policies when needed.

A Culture of Data for Decision-Making

Instructional leaders should cultivate a data culture within the organization. Data in school and institutions may consist of student records, curriculum materials data, program data, administrative data, and financial records. These data may not be compiled in an electronic or a usable form and may be stored in various places, not in a single repository. Hence, data needs to be organized to make it easily accessible. When a data culture exists, members of the institution know the need to collect relevant data to be transformed into knowledge for planning and organizing (Tolley and Shulruf 2009; Petersen 2012). The institutional leader needs to cultivate this culture.

Data management and analytic capacity can be developed among the staff so that the data collected can be analyzed to answer strategic questions. For example, in a New Zealand secondary school's transformation by the Academic Counselling and Target Setting (ACTS), the aim was to improve student success by increasing academic performance through a systematic data sets in the form of individual student's academic profiles (Tolley and Shulruf 2009). At the same time staff were encouraged to work on the academic performance of the school (Tolley and Shulruf 2009). The strategic plan of the institution had identified the educational knowledge available and what needed to be improved, and hence, a revision of the data management system was

done to include more relevant data analysis schemes which could enable longitudinal analysis, with feedback for the data management system and teaching staff (Tolley and Shulruf 2009). This intervention improved the culture of data among the staff, increased the use of data stored on the schools' database, and significantly improved the quality of data for the use academic counsellors as well as for student achievements (Tolley and Shulruf 2009).

Databases which can be used for accountability can be found in national education management information systems (EMIS). EMIS should be designed to manage and organize the information in a country's education system for education development and meaningful change. EMIS is usually centered within the Ministry of Education of a country. In countries with a suitable political-economic framework and demand for data-driven information, EMIS is successful (Tolley and Shulruf 2009). However, EMIS should not just be exclusively for educational data collection from all levels, but should instead be a means for institutions to collaborate with the central administration so that stakeholders can also transform data for decision-making in their context (Tolley and Shulruf 2009).

A data culture for research and decision-making should be cultivated so that there is easy access to databases (Petersen 2012). This is provided through many nontraditional learning platforms. Learning analytics has also potential for collecting data through new learning environments.

Developing Instructors' Capacities in Technology and Pedagogy

Institutional leaders need to prioritize the changes to be implemented according to the needs of the institution. In order to provide quality education, the improvement which should be carried out in classroom instruction and practice should be balanced with the vision of the institution as well as in other aspects (Hopkins 2001; Heaven and Bourne 2016). The teachers as implementer of the innovative practices will determine the success of

the changes. Hence, the teachers' understanding of the change, and their support in putting the change into practice, and for adapting the change into their particular classroom, needs to be developed (MacBeath 2009). This adaptation to the specific classroom is required as there is no one specific measure of accountability which can be used to measure the inner workings of the classrooms (MacBeath 2009).

Capacity Development

Developing the capacities of the instructor is an important aspect of instructional leadership. The level of involvement of the instructional leader can determine the success of an innovation or educational reforms (Heaven and Bourne 2016). Although teachers and instructors may be positive about the use to technology, their confidence, competence, and discomfort on the changes in instructional practice with a new technology may hinder the experience (Young 2016).

Instructional leaders should provide adequate professional development before and during the project (Young 2016). Continuous professional development has shown to be effective in developing teachers' confidence, competence, and usage of technology while improving their perception toward a new technology, even among those less skilled in technology (Young 2016). Hence, instructional coaching, mentoring, and training are required for building staff motivation and beliefs (Heaven and Bourne 2016; Kopcha 2010; Leithwood et al. 2004). Building staff capacity can encourage efforts in developing new pedagogies to cater to individual learner differences and encouraging creativity (Heaven and Bourne 2016; MacBeath 2009). The teachers' understanding and commitment to change is a major contributor to the success of the policy or reform and cannot be replaced by specific curriculum, elaborate text books, and other well-designed materials (MacBeath 2009). Hence, developing capacities is important for the instructional leader as he builds relationships among his staff (Heaven and Bourne 2016). He should also allow instructors sufficient time to prepare resources, practice strategies, share experiences,

and empower them to innovate (Heaven and Bourne 2016; Young 2016).

The role of the instructional leader to motivate and instill the belief in the reform among his staff is an approach toward quality (Gregg et al. 2018; Heaven and Bourne 2016). Implementing an educational innovation may require a change in pedagogies and approaches to teaching. Hence, sharing best practices and giving feedback for the implementation may assist the instructors in creating innovative and quality resources (Heaven and Bourne 2016).

Designing Learning Experiences

The educational institution which is accountable to its stakeholders should provide quality learning experiences for the learners. The instructional leader who is an expert in the educational innovation may also be able to guide, mentor, and coach the staff involved. However, if the instructional leader is unable to provide the support, he should consider investing in learning design and faculty development (Gregg et al. 2018).

Quality in teaching and learning refers to designing quality learning experiences and providing quality educational resources. For example for a technological innovation, the instructional leader would need to ensure there are sufficient curriculum resources in the digital form (Young 2016). These resources may be sourced from external providers or developed internally by the instructors or a team within the institution. Hence, a team of competent learning designers who have the ability to develop effective learning experiences for any delivery mode, whether online or blended or face-to-face, should be made available to ensure the success of the innovation (Gregg et al. 2018).

Most teachers teach the way that they were trained in (Gregg et al. 2018). Hence, if a new educational innovation is implemented, teachers should be trained to teach in the new pedagogy. For example, if an online course is going to be provided, it is only fair that the online course should be well-designed and that the instructors would be qualified and confident online course moderators (Gregg et al. 2018). Hence, instructors should be trained to be competent and qualified as

online instructors to ensure quality is maintained (Gregg et al. 2018).

The instructional leader may need to decide on the funding possibilities for developing capacities. Material development could be outsourced or developed by an in-house development team, and staff need to be trained to be skilled in learning design and for implementation of the educational innovation (Gregg et al. 2018). Before the course is offered, learning designers are required to design the learning environment, but when the course is implemented, instructors are needed to teach the course so that they can use, manage, and optimize the technologies in the courses (Gregg et al. 2018). Teachers may need to be trained as learning designers and online course instructors.

Instructional leadership plays a significant part on student learning. By developing the capacities of instructors, promoting a vision, and ensuring resources and processes are in place for instructors to teach well, it can have a positive impact on students' learning (Heaven and Bourne 2016; Leithwood and Riehl 2003).

Technology Infrastructure

Technology has been used to deliver instruction in both for online and for blended learning. The growing number of MOOCs and e-learning platforms attest to the feasibility of these platforms with the availability of data for accountability. However, are students provided with rich learning experiences using these technologies? To ensure the quality of instruction is maintained, instructional designers provide support for faculty and also manage new content delivery tools (Moore and Fodrey 2018). Administrators have now to align resources for the most effective and efficient models of delivery of instruction (Moore and Fodrey 2018).

Moore and Fodrey (2018) suggest a model for technology infrastructure for the educational institution. As instructional leaders seek to deliver quality experiences, they need to take into consideration the institution, student, instructors, and technology. Technology infrastructure

consists of the following components: the systems, objectives, personnel, and evaluation (Moore and Fodrey 2018). However, there urgently needs to be a systematic way to identify, evaluate, and implement tools that can support the mission and vision of the institution as the technology infrastructure service is a critical factor for the successful uptake of the technology (Alsabawy et al. 2013). Each of the components of technology infrastructure is discussed next.

Systems

In the systems component, firstly, the format or delivery method to create instructional content needs to be determined, followed by the platform or tool to deliver the content (Moore and Fodrey 2018).

There are a variety of delivery methods. When Moore and Fodrey (2018) discussed on the delivery of distance education, they focused on webinars, lecture captures, and e-learning modules. Webinars are synchronous recordings which enable direct interaction between instructor and students which can be recorded and archived as videos. The recordings can be done using a web platform, presented from the instructors' laptop, and normally accompanied with visuals and audio, and normally Powerpoint slides. Interactivity in webinars can be captured through polls, questions and feedback, and chat-based text. Lecture captures, on the other hand, are the digital representation of the lesson in the classroom as the recording is done during the lecture. These lecture captures can be viewed synchronously at a distance or accessed after the class session. However, lecture captures are not completely synchronous as there is normally a delay in transmission, and when synchronous activities like polls are conducted, there may be a lag time. Finally, e-learning modules are difficult as developing a self-paced module for instruction with sufficient interaction may take a lot of time. Interactive quizzes, and other user interactivity such as clicking and mouse-overs to reveal information and feedback can promote interaction. These modules do not require real-time interaction, but will need to be designed for self-paced and self-directed learning.

After the system for the creation of content has been determined, the delivery of the content created needs specific tools. Tools like Adobe Connect and Skype for Business have possibilities for video conferencing. Preset and Andrews (Preset and Andrews 2015) divided the range of tools into the “magic quadrant for web conferencing,” where the tools are divided based on the products and their features as *leaders*, *challengers*, *visionaries*, and *niche players*. Leaders are companies with tools which have a large market share relative with products which have a wide range of features, while niche players are companies which have good technology, but because of their service, they are limited to a niche area (Preset and Andrews 2015).

Objectives

The technology which is selected should serve its purpose in education. As Moore (2014) states technology should support learning and not just be added because it seems to be fun. Hence, the learning objectives must be clearly established, and the technology selected must be aligned with the objectives. This will also set the scope for evaluation as evaluation of the technology tool is based on the original purpose of the tool. Moore and Fodrey (2018) gave an example of an instructor who wanted his students to acquire specific concepts before they could be taught application and critical thinking. For this purpose, they suggested an e-learning module to cover fundamental concepts to be published and distributed to students using Adobe Connect. Quizzes in the module could provide the knowledge check, and the scores could be linked to an LMS, which would provide for the evaluation and accountability in the module.

Evaluation

The evaluation of the effectiveness of the tool for achieving the objectives is an important measure of success (Moore and Fodrey 2018). The evaluation should be done in two stages: initial evaluation of the tool before it will be used and continuous evaluation, which occurs after the implementation. Evaluation should be an essential component that needs to be done to determine

whether the technology meets the objectives of the course (Moore and Fodrey 2018). Evaluation may require mechanisms for feedback from the users and not just a technical evaluation.

Personnel

As technology infrastructure is an important requirement for an e-learning course, institutions need to ensure there is an instructional designer within the institution. The instructional designer needs to be able to work with instructors in integrating technology and aligning technology to learning objectives (Moore and Fodrey 2018). For instructors who have little experience in integrating technology in their teaching, this support will be beneficial. However, for instructors who are already adopting the technology, the instructional designer can help think of new ways and perhaps new tools to use innovatively in the classroom (Moore and Fodrey 2018). Another function of the instructional designer is that he will be the connection with the technical personnel within the IT Division. For example, an LMS administrator may not know which tools instructors and students require or work best with and may not know of the technical requirements such as bandwidth during deployment. These are decisions related to the pedagogy rather than the technology and may be addressed by the instructional designer. Hence, having an IT division team with an instructional designer involved could provide a more holistic and sustainable support structure (Moore and Fodrey 2018).

In conclusion, combining the knowledge of the pedagogical needs with the technological infrastructure, such as the Internet connectivity and Wi-Fi, may assist in addressing some of the problems of integrating technology in instruction (Young 2016). Gregg et al. (2018) suggest working strategically with educational technology vendors, either by developing specific solutions for your organization or adapting what is already in the market to the instructional needs. However, in order to determine which solutions work, they suggest that staff and faculty members be included as key stakeholders in making decisions. The staff and the instructional designers should decide on the educational technology solutions.

As there may already be many different applications being used in the institution, the first step may be to compile information on the existing applications and their licenses to determine whether there are overlaps in functions (Gregg et al. 2018). Assessing the instructors' needs to ensure that the solutions provided meet the requirements, providing updates on the procurement of the solution, and enabling the instructors to provide feedback on the use of the solution provide the instructors with a sense of responsibility for the solution and improve buy-in (Gregg et al. 2018). However, there is no one specific solution for everyone, and finding a means to obtain feedback on the technology to be used is important for the institution.

In conclusion, the technology infrastructure required needs to be considered with the instructors and their needs. The systems for creating and delivering the content, objectives, technology tool, mechanism for evaluation, and feedback and the personnel for creating the technology should be developed.

Community Involvement

Other stakeholders in the education process should be involved in ensuring that quality education is provided. Involvement of the staff, students, parents, community members, and other stakeholders can be used for a stakeholder-based approach to decision-making (Raish et al. 2018). The stakeholder-based approach which involves the community in solving issues takes on a horizontal accountability approach for formulating strategies, decision-making, and evaluation of education for improving quality of services in institutions (Hooze et al. 2012). This ensures transparency in the process of running the institution, where different perspectives and backgrounds are taken into account, and hence, can also gather buy-in from the community in the process of change (Raish et al. 2018). A shared responsibility is developed by students and their parents to members of the community and the community as a whole to ensure that effective and quality services are provided.

A shared, collaborative, and participative concept of leadership in this way can contribute to the organization's success (Leithwood et al. 2004). There are several aspects of community discussed in this section, parents and guardians as support for the education system, development of the online learning community for students and for teachers, as well as support from the community.

Parents and Guardians

In the school system, parents and guardians have a role in supporting their child's education. However, parents may not be aware of how they can support their children's education, and what role they should play. This is even more obvious when technology, for example, e-learning, is implemented in schools. Hence, the instructional leader should have a set of guidelines to inform parents of their roles, orientations, and the expectations, so that parents and guardians can be effective coaches (Raish et al. 2018).

Students' Online Learning Community

Successful e-learning happens when an online learning community is built. Students need to connect to their instructors and be active participants in the online interactions. However, students may be resistant to interacting online. One way to address this problem is having students take self-readiness assessment for individualized feedback on how prepared students are for online learning. This feedback can be used to identify students' strengths and weaknesses for the online learning environment (Raish et al. 2018). Next, during the e-learning process, the instructor needs to be able to connect with the students. This means ensuring personalized instruction and maintaining online interactions with students. The instructor will need to acquire new skills for learning and mentoring online. Hence, capacity building for the instructor to teach and mentor his students online is required. The culture of learning needs to change in the online environment to be more collaborative and constructivist as the instructor builds and supports an online community of learners.

Teachers' Online Learning Community

Capacity development of the online instructors can take place in the form of formal as well as informal professional development. Teachers and instructors themselves need to be supported in implementing new innovations. Gregg et al. (2018) suggests developing informal communities within the institution for this purpose. This community should be hosted on an online platform to support each other, share best practices, develop their skills, and also motivate one another in using the innovation. A community of practice for teachers and instructors practicing online learning is important as this fulfils the human social need. Just as a group of teachers would discuss their academic work in the staff room, providing a "workspace" online to conduct discussions can enable teachers to exercise their professionalism. Teachers and instructors may face problems while teaching online and having a technology support group which provides support by mentoring and coaching online motivate and empowerment them to use technology (Gregg et al. 2018). A community of practice with an instructional leader who is well versed in technology and pedagogy would be able to support the community and each individual. In addition, each member of the group also supports one another. This collaborative approach is more sustainable as teachers develop their expertise and mentor their peers. This in turn develops a culture of collaboration as there is a shared purpose and vision in using the technology and develops other leaders in the use of technology (Gregg et al. 2018).

Professional e-Learning Community

A larger community of practice among the professional e-learning community can be a source of information. Most professional e-learning communities believe in providing open educational resources for all and are helpful in sharing on topics such as institutional leadership, technology, instructional design strategies, online instruction, and policies impacting online education (Gregg et al. 2018). Many of these communities make up of blogs and podcasts to regularly post online. Gregg et al. (2018) suggests that the

instructional leader can identify professional networks which are appropriate for the institution and its community, and to participate in conferences, and subscribe to related professional organizations and blogs, as well as conducting related research.

In summary, community involvement includes parents and guardians supporting their children, learning communities which support students' and teachers' learning online, and being a part of a larger e-learning professional community.

Conclusion

In implementing a change or an innovation for institutional improvement, school and institutional leaders are accountable to their stakeholders to provide quality education. In setting the strategies for school and institutional improvement, the instructional leader needs to instill a shared vision in the institution to ensure that students, teachers, instructors, parents, and other stakeholders are convinced that a reform or a change will bring about quality teaching and learning. The instructional leader may need to develop a vision, relevant policies to ensure all the stakeholders are aware of their roles and function, and develop their capacities in both technology and pedagogies. The innovation should be customized to the institution, and the stakeholders should be involved in the planning.

Instructional design and development of staff capacities should not be neglected to ensure that instructors are capable of providing quality learning experiences. In addition, adequate technology infrastructure suitable to the pedagogy required should be provided. Finally, support can be garnered from the communities for institutional improvement as parents and other stakeholders get involved in the education process. In addition, learning environments for build communities of learners should be supported through online mentors, and these mentors and instructors should be provided a platform for developing their own professional learning communities. Other professional communities can establish support for

professional development as best practices and strategies are shared.

Hence, there may be other factors which are not discussed which may contribute to the success of an innovation in the intuition such as individual staff as innovators, having an institutional champion, and students as drivers of the innovation (Czerniewicz and Brown 2009). However, these are not discussed as the contribution to the reform is small. Any improvement effort or innovation should be a system-wide approach in order for successful integration with technology and should be embedded seamlessly within an organization in order to have institutional acceptance and for the institution to strive toward being the top quality in innovation.

The purpose of innovation in education is to provide quality education for the digital natives of the imagination age. In order to be accountable to these students, their parents and other stakeholders, school, and instructional leaders need to develop a vision, consider changes in policies, create a data culture, build staff capacities, develop learning communities, and provide for involvement of stakeholders in driving the innovation.

Summary

Schools and higher education institutions need to continuously improve in efforts to provide quality education as these institutions are accountable to their students, parents, members of the community, and other stakeholders in education. Students need to be equipped with the skills and knowledge for future jobs in the imagination age. However, school and institutional leaders may not be equipped with the skills to propel their institutions forward in a technology-rich world. Hence, schools and institutional leaders need to be supported in their role as instructional leaders to improve instructional practice and developing human capacity. Some suggestions and guidelines are provided to support leaders in inspiring the institution in achieving a shared vision, developing policies related to

the vision, building a culture of data for decision-making, developing instructors' capacities in technology and pedagogy, and providing the technology infrastructure and strategies for community involvement.

Cross-References

- ▶ Attendance Records, Educational Management
- ▶ Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption
- ▶ Data Mining for Educational Management
- ▶ Decision Support Systems and Knowledge Management in Education
- ▶ Different Methodological Approaches to Considering the Adoption of ICT
- ▶ Digital Citizenship, a Sociocultural Snapshot
- ▶ Human, Social, and Ethical Aspects of Information Technology Management Systems
- ▶ Information Technology for Local Education Authorities and School Districts, Use of
- ▶ IT in Educational Institutions, Planning and Development of
- ▶ Leadership on Information Technology in Education
- ▶ Modeling the Process of Information Technology Innovation in Education
- ▶ MOOCs, Teacher Professional Learning and Deep Learning Conversations
- ▶ Restructuring Teachers' Knowledge for Teaching With Technologies with Online Professional Development
- ▶ School Management Software in a Primary School in Victoria, Use of
- ▶ Security and Privacy of Information Technology Management Systems
- ▶ Situative Perspective and Determinants of Technology Acceptance in Educational Technology
- ▶ Social Networks in Higher Education Management
- ▶ Teacher Education and Professional Development for Technology Integrated Teaching
- ▶ Teacher Education, Thinking about ICT

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Survey

- [Predicting ICT Skills and ICT Use of University Students](#)

Sustaining Change and Adaptation

- [Sustaining Digital Technology Use in Professional Communities](#)

Sustaining Digital Technology Use in Professional Communities

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Synonyms

[Adapting to new software and hardware](#); [Learning and training with digital technologies](#); [Long-term digital practice](#); [Professional development](#); [Sustaining change and adaptation](#); [Using digital technologies](#)

Introduction

The progression and evolution of information and communication technologies (ICT) has brought about large amounts of change structure-wise, including trade expansion, economic, and even concepts of globalization. Access through ICT has led to the enhancement of the availability of information. Looking back to the late 1990s, the Internet was just becoming available and mostly existed on university campuses or for the military. After a decade, Internet access and other technologies were seen more widely, and now many people have access to them.

In the last few years, it is undeniable that individuals, schools, colleges, and companies are spending more money and resources on technologies. However, there seems to be a lack of ongoing information about peoples' perceptions towards digital technologies, and how these might affect organizational structures or practices. This article explores this issue, with how individuals sustain their uses of digital technologies

over long-term periods; it will consider a case of Malaysian individuals' perceptions of uses of digital technologies, how change and adaptations are being sustained, compared to those in the United Kingdom (UK). It will explore drivers that contribute to how individuals adapt to ongoing changes that are happening in the technological world, and based on current research, offers a model for future development of sustained practice.

Background

Businesses are creating and capturing value, using ways of interacting and communicating, benefiting from where and how people are working, all arising from and due to the influence and changes of technology in the global world that ICT supports and enables (Cascio and Montaelegre 2016). Big data and machine learning, advanced robotics and drones, cloud and mobile computing, and technologies that are clean-energy are technologies which are currently at the emerging edge, transforming and driving the starting points of some businesses globally.

However, evidence from studies undertaken over the past 20 years or more (e.g., Gao et al. 2011; OECD 2015; Tatnall and Davey 2014) shows a repeated lack of long-term uses of digital technologies by teachers, trainers, and employees to support what would be regarded as effective enactment, for their teaching, training, or work-based practices. While studies have identified drivers and barriers (e.g., Conole 2016; Porter and Graham 2016), studies exploring reasons for long-term sustained uses have not emerged as frequently (e.g., Mumtaz 2000). Developing effective practitioner enactment (Heitink et al. 2016; Khan et al. 2016) requires detailed knowledge about relationships of factors and features that enable teachers, trainers, and employees to understand how and why they can use digital technologies in their respective work areas. Features and factors enabling use not only concern professional attitudes and understanding of technological affordances and facilities but also

attitudes and understanding towards technologies and, importantly, innovation. If appropriate learning, teaching, training and work-based uses are to develop over periods of time, rather than being restricted to the short-term, to accommodate rapid technological changes, then enactment should be concerned not just with pilot and project-based uses, but with long-term interactions where adaptation and change facility are inherent to professional practice.

Factors that can affect an individual's attitude towards any kind of new technology might be their age, gender, or even their peers' attitudes and perceptions. There are challenges when introducing new technologies, such as achieving user acceptance, but at the same time, organizations are also trying to retain levels of acceptance when it comes to performance and productivity (Ahmad 2014). Reasons why companies or organizations are introducing new technologies can be to increase quality and productivity, to reduce costs and dependence on skilled labor, to be up-to-date, to retain their position when competitors also introduce new technologies, and to change relations and interactions among various groups within organizations (Dawson 2007). In many businesses and organizations (including those that are educationally focused), there is an increase of participation among employees who are remote or faraway. Technologies can assist and expand the number of employees who are collaborating or working together with technology tools such as the Internet, shared databases, and internal intranets. Regardless of location (accepting Internet accessibility), technology enables sharing challenges that are faced by remote employees to be overcome (Schraeder et al. 2006).

The most unavoidable factor in the business world is change. It is important for an organization's toolset to be upgraded on a regular basis, and furthermore, their employees and staff need to accept changes applied. Changing employee and staff perceptions and behaviors cannot be done and forced overnight; it is a long-term objective, a critical factor being the provision to the employees of the full context of the changes, as this will allow them to understand the need for such changes (Croft and Cochrane 2005). When it

comes to organizations, it is the role of managers to provide justifications, reasons, and rationales as to why it is necessary to make these changes in order to create a degree of readiness, as this will increase the likelihood for the employees to accept and participate in the changes applied (Ford et al. 2008). Furthermore, managers play a very important vital role in coordinating, controlling, and leading employees within their businesses, to ensure that any technologies that are integrated into use are technologically fit for the purposes of the organization (Kao et al. 1996).

A factor that can influence a manager's performance is, firstly, training. Training and sufficient guidance should be provided to employees on how to use new technologies if the technologies will be an essential tool for the business, and such professional technological training needs to be taken seriously, with an appropriate transition flow (Alan 2010). This should be considered and viewed as a vital investment (Reese and Porter 2008). A further factor for managers to consider is modern technology's mobility. What most managers look for are tools that enable them to do their tasks at any given time and even for them to bring their work home or their abilities to complete it in any location beyond the office. Mobility of the technology helps in increasing profitability and also productivity (Pfano and Beharry 2016). Usefulness, when it comes to office technology, is a factor; and technologies that are indeed useful may well be used every day (Billhelf 2006).

In order to implement a technology change successfully, areas that need to be addressed effectively include any internal conflict challenges or resistance by employees, adequate consideration and planning of an employee's training, multigenerational workforce concerns, and communication. All of these can be addressed, involving an implementation plan that is adequately conceived, a training plan that is feasible and potentially effective and, lastly, when it comes to communication between management and employees, there must be open communication (Delaney and D'Agostino 2015).

In this digital era, the use of computers has become easier, offering benefits that arise from

new functionality. It is undeniable that all areas of production in many organizations have been transformed by the computer (McConnell 1996). Many organizations are devoting their resources so that their employees are gaining substantial training, as training is seen as a “must” to keep oneself updated. The University of Virginia, for example, is constantly providing computer training for their staff (some two to three thousand in number) with workshops that have involved total participant numbers up to 2000 for the last 4 years. The training hours total about 3.86 per employee per year (Friedberg 2003). Subsequently, organizations are showing benefits as a result; one organization that spent a great deal on purchasing a large number of computers showed a greater reciprocity when it comes to skilled labor (Eric and Loren 1997; Lehr and Lichtenberg 1998). Since the 1990s, there has been an increasing awareness regarding on-the-job training as the most appropriate method of educating and teaching employees necessary skills (Jacobs and Jones 1995). Furthermore, support from peers and supervisory personnel are variables that have contributed to the effectiveness of training programs (Bates et al. 2000).

On-demand businesses are now combining technology with information technology, so that these companies can be profitable, responsible, and rapid. Today, enterprise considers flexibility as a key factor. Flexibility in this sense is concerned with adaptability when responding to any kinds of new demands in the current market and taking whatever opportunity may come along (Tohidi 2011). User satisfaction with using technology is undeniably important. What contributes towards how well any resources are being utilized in an individual’s work life depends on their aptitude, ability, attitude, and even beliefs about information technology (Venkatesh 1999).

Cases in Malaysia and the UK

An example study which illustrates key points about sustainability of digital technology practices, conducted in the UK and Malaysia (Passey

and Lee 2018), gathered qualitative data about individual approaches to sustaining uses of digital technologies for learning, teaching, and training. Interviewed participants had used technologies in their careers for learning, teaching, and training purposes for many years. The study gathered evidence about:

1. How long the participants had been using technology devices to support learning, training, or employment.
2. Over that time, what hardware changes they had encountered, and which devices they had used at different times over that period.
3. The software changes they had encountered over that time, which software they had used, and when they started to use these.
4. What their experiences were in terms of performance when they started to use new hardware and software – for example, whether it went down, stayed the same, or went up and how long these sorts of shifts in performance lasted.
5. The benefits they experienced from uses, whether these were what they would regard as the most important benefits, and whether these shifted at all over time.
6. How they managed to maintain uses of technologies when software or hardware changed, and what they did so that they could use the new or updated software or hardware.
7. Whether there were other people around them, in their situations or context, which made a difference in this respect, and if so, whether they would say those differences were positive or negative.
8. Whether there were particular contextual factors that had been important in helping them to adapt to new technologies at certain times. For example, whether they would rate any of the following as being important to sustaining their enactment in the school, college, university, or work:
 - (a) A shared vision of technological uses
 - (b) Empowerment from leaders
 - (c) Implementation planning
 - (d) Consistent and adequate funding, either personally or from the institution

- (e) Equitable access, compared to others
 - (f) Ongoing professional development
 - (g) Technical support
 - (h) A framework of how to use the technologies in the institutional curriculum or work plan
 - (i) The ability to choose when to use the technologies
 - (j) Assessment and evaluation of their practices using technologies
 - (k) Engaged communities of users
 - (l) A supportive external context at home or outside the institution
9. Whether any of these factors, or others, hindered their ability to adapt to technology changes over time.
 10. How they considered the value of uses of technology overall – for example, as a requirement, or something that is useful, as a tool, an add-on, something about which they need to be kept informed for their learning, training, or work.
 11. Whether they thought it was important to maintain contact with and integrate technology with their learning, training, or work, and if so, why they thought that was so.
 12. What they thought the main personal factors or characteristics were that enabled them to adapt to technology changes over time.

A total of 16 respondents from Malaysia and 14 in the UK participated in the studies. Most were men (20 compared to 10 women), as shown in Table 1.

From Table 2, it can be seen that most of the respondents in the study coming from Malaysia were between the ages of 21 and 40 years (a younger adult group), whereas the respondents in the UK were mostly aged between 41 and 60 years (a middle-range age group).

Table 3 shows that most of the interviewees had been using technologies for 10–20 years in Malaysia, while in the UK most had been using technology for longer time periods, for 21 years or more. Compared to the UK, participants in Malaysia had used technology for shorter periods of time.

Sustaining Digital Technology Use in Professional Communities, Table 1 Genders of the participants interviewed

Gender	UK	Malaysia	
Women	6	4	10
Men	8	12	20
Total	14	16	30

Sustaining Digital Technology Use in Professional Communities, Table 2 Age ranges of interviewees

Age band	Malaysia	UK	
Between 21 and 40 years of age	14	2	16
Between 41 and 60 years of age	2	11	13
61 years of age and above	0	1	1
Total	16	14	30

Sustaining Digital Technology Use in Professional Communities, Table 3 How long technologies had been used by the interviewees

How long technologies have been used	Malaysia	UK	
For up to 10 years	9	1	10
Between 11 and 20 years	7	3	10
Between 21 and 30 years	0	6	6
31 years and over	0	4	4
Total	16	14	30

Experiences of Long-Term Sustained Users of Digital Technologies

When asked about their experiences with hardware changes over the times they had been using the technologies, and what kinds of devices they had used over that period, most Malaysian participants stated they had used laptops (8 respondents), tablets (3 respondents), CD-ROM (Compact Disk Read Only Memory)/floppy disks (3 respondents), mobile telephones (7 respondents), monitors (5 respondents), thumb drives/external hard-disk drives (3 respondents), and mobile technologies (2 respondents). Some also identified the Internet, Microsoft (MS) Windows, televisions, sensor devices, gaming devices, digital audio recorders, the iCloud all system, telephone cables, printers,

keyboards, mice, and Wi-Fi that they had used before as time went on. Compared to the UK study (Passey and Lee 2018), respondents in the UK related hardware changes they encountered based on periods of their life such as their childhood, their first job, etc.

When asked about software changes, Malaysian respondents clearly recognized changes when they moved from one software to another such as Microsoft (MS) in general (5 respondents), MS Word (3 respondents), MS PowerPoint (3 respondents) and MS Excel (2 respondents), and 9 respondents recognized the changes more when it came to using Adobe software like Illustrator and Photoshop. Other software changes identified were related to more specific packages, the iPhone Operating System (iOS), virtual private networks (VPNs), Oracle, computer languages such as Turbo Pascal, visual basic (VB), Java, standardized query language (SQL), SAS Visual Analytics, Webex, Shem's Risk Management System (SRMS), fourth generation language (4th GL), computer-aided design (CAD), X-Mind, and Figma Sublime software. Respondents from the UK did not relate software changes to periods of times when they used them, instead identifying the changes of software in a more general way, concerned with features and functionality of the software. This difference between the respondent groups might be related to the different lengths of times that the respondents in the two countries had used technologies.

When interviewees in Malaysia were asked about their experiences in terms of performance of new hardware or software, most respondents agreed that performance had increased significantly (6 respondents) and also they noted productivity increases too (4 respondents). Some agreed that technologies had become more user-friendly (3 respondents), loading time was faster (2 respondents), their learning improved the more they used it (1 respondent), it was more consistent (1 respondent), and hardware had got better (1 respondent). A few participants thought technology performance had stayed the same, or it took some time to adapt to it, or some trends did not fit their preferences. In the UK, respondents referred to more specific categories of

performance of the new hardware and software in terms of increased efficiency, enhanced access, improved performance, and enhanced ease of use.

Interviewees were also asked about the benefits they had experienced from the use of technologies. Most in Malaysia said it definitely improved their productivity (7 respondents), it also saved time (3 respondents), and helped them to communicate and work more easily (3 respondents). Other benefits mentioned were increased convenience, efficiency, gaining more security, and greater experience and basic knowledge of using the software over time. This pattern was similar to that recognized by the UK respondents.

Regarding the question of how they managed to maintain their uses and address challenges of changing technologies and what they did in order to use the updated software or hardware, most Malaysian respondents said that they sought help online either through a tutorial/guide/wikiHow/forum (8 respondents), YouTube (3 respondents), or Google (2 respondents). Five respondents said they taught themselves how to use the software, while two respondents went on many courses or read books and just updated on the basis that was needed. Three respondents asked somebody else or just tried it out themselves, and one respondent said they tested before updating or just went on a training course when the programs were much more sophisticated. The UK participants related similar responses, but, perhaps related to their age profile or not, the way they resolved their challenges was by talking to people who were "IT savvy" which they said "helped them a lot." They were also influenced by their children's uses of technology, including using technologies that enabled them to communicate with their children. Additionally, they said that support units in their places of work or employment, such as IT support, helped them too.

Table 4 shows interviewee responses regarding questions about particular contextual factors that they regarded as being important in helping them to adapt to new technology. All of the contextual factor specified were important to many respondents, but those highlighted especially were implementation planning (29 responses in total) and engaging communities

Sustaining Digital Technology Use in Professional Communities, Table 4 Contextual factors influential in maintaining sustained uses of technologies over time

Contextual factor	UK Yes	UK No	Malaysia Yes	Malaysia No
1. A shared vision of technological uses	11	3	14	2
2. Empowerment from leaders	12	2	14	2
3. Implementation planning	14	0	15	1
4. Consistent and adequate funding, either personally or from your institution	12	2	14	2
5. Equitable access compared to others	8	6	14	1
6. Ongoing professional development	9	5	14	2
7. Technical support	6	8	14	2
8. A framework of how to use the technologies in your institution's curriculum or work plan	11	3	14	2
9. The ability for you to choose when to use the technologies	7	6	12	4
10. Assessment and evaluation of your practices using technologies	10	4	14	2
11. Engaged communities of users	11	2	15	1
12. Supportive external at home or outside your institution	10	4	13	3

of users (26 responses). The least commonly highlighted was the ability for them to choose when to use the technologies (19 responses). It is clear that respondents rely upon a variety of supportive factors, rather than any specific factor or group of these.

From the details within Table 4, it is clear that the shared vision of technological uses, empowerment from leaders, implementation of planning, consistent and adequate funding from the institution, a framework of how to use the technologies in their institution's curriculum or work plan, and engaging communities of users showed similar high response rates for both countries. The majority of respondents agreed that these factors were key in influencing them on sustaining the use of technologies over time. The responses of Malaysian and UK participants were different when it came to accessibility of the technologies, technical support, and professional development. The younger age range adults from Malaysia said more commonly that the factors of accessing technologies when they chose to, and to seek support easily were important, whereas a lower proportion of the middle aged group from the UK indicated the importance of factors concerned with when to use the technologies and to access technical support.

When asked if the factors mentioned had hindered their ability to adapt to technology

changes over time, some indicated that this was the case. While some indicated hindering reasons like limited funding, only one respondent indicated that implementation planning was a hindering factor.

Interviewees were asked how they considered the use of technology overall. Some respondents in Malaysia said that it was essential and necessary to their work (4 respondents). Two respondents stated each of following: as a requirement to adapt to new technology, or something that is useful; or as a tool, an add-on, or something that you need to keep involved in with how you learn, train or work. Other participants stated that technologies are needed to maintain today's standards, to evolve, to keep up with changes of technology, as a vital tool, making sure technology can be used, but to make sure that it is fully utilized, to engage students, or help customers to meet their requirements, including uses for communication. In the UK, responses generally indicated the essential value of technologies, to support and enhance productivity and communication.

Participants were asked if it was important to maintain contact with and integrate technology with learning, training, or work. Many participants in Malaysia agreed that it was important (12 respondents). The reasons given for this were to use technology to appropriately encounter

obstacles that it is easier to stay connected, to solve problems immediately, to stay up-to-date in the IT industry, that the world is growing and so technology is surrounding us, and to make sure that we are updated with technological enhancement. A similar pattern of responses was gained from the UK participants, who indicated that changes in technologies were providing positive enhancements for addressing issues and challenges but that these might need to be explored by the individual within their specific contexts.

When participants in Malaysia were asked what they thought were the main personal factors or characteristics that had enabled them to adapt to technology changes over time, many of them said self-exploration (3 respondents), being humble and willing to learn things (3 respondents), personal interest (2 respondents), and curiosity of new technology (2 respondents). Others indicated the need for a positive attitude towards technology, enjoying learning, having an inquisitive nature, having a passion with gadgets, confidence, being positively responsive to change, and being sensitive to what is out there. The UK participants responded similarly, but highlighted key characteristics such as inquisitiveness and having a positive attitude towards technology.

It was clear from both sets of respondents that personal factors or characteristics were vitally important in enabling individuals to maintain their interest in and abilities to accommodate change with technologies over time. The role of personal characteristics and attitudes is shown across these samples of long-term users to be significant; the role of technical training is stated far less. Rather, it is access to individuals or resources that can support technical training that is reported as being more important than the technical training per se.

Factors that Contribute to Sustained Uses

Based on previous research literature and on the analysis from this case, it is shown that participants who have been involved in long-

term use of technologies to support their learning, teaching, training, and work-based practices are finding ways to accommodate to change in technologies. With regard to using previous hardware and devices, individuals may recognize that they had noticed changes with the introduction of certain technologies – mobile technologies, tablets, laptops, floppy disks, CD-ROMs, and thumb drives. In terms of software changes, it appears to depend on the specific forms of software that individuals need to use and choose to use, but individuals may recognize changes in software that have been available over quite long periods of time, such as Microsoft and Adobe products, as well as more specific software applications that are used for specific purposes. Reasons for noticing these changes may well be related to advancements in the technologies that have brought significant benefits, as those who sustain uses highlight increases such as those in performance and communication, and greater consistency in hardware, leading to improvements in productivity due to increased speed and loading time, with less waiting time involved. Regular software updates are noted to introduce friendlier user interfaces leading to greater overall usability. Importantly, “practice makes perfect” can be an overall concern of long-term users – by consistently exploring, accommodating beneficial affordances, and using software; over time, this leads to its becoming easier to use. The introduction of smartphones, tablets, and laptops can be noted to enable access and work to be done anywhere and anytime, leading in many cases to increased convenience, efficiency, and productivity. However, the dependence on technologies and the need to respond anytime and anywhere can be seen by some as an issue that needs to be considered and managed carefully, to ensure that personal time is not invaded inappropriately.

To enhance the learning of new facilities in technologies, materials and sources on the Internet are increasingly mentioned as a preferred choice, with many tutorials online which can help. Some long-term users indicate that they prefer to do things on a trial and error basis, while others prefer to refer to more documentation. With the need to use and apply new hardware

or software to an individual's context, a single approach may be adopted by an individual, but a variety of approaches are likely to be taken across a population.

Technological advancements have not only provided an increase in productivity, performance, efficiency, or convenience in work and jobs but they have been recognized by long-term users as creating a platform for communication across individuals. Some significant responses highlight benefits, such as the positivity of technology advancements which helped a single child deal with loneliness, as well as how older generations are accepting technological changes that can be an inspiration to others. In some cultural contexts, such as that in Malaysia, if younger people see their parents or older generations using smartphones and tablets with ease, it is felt that this may well trigger a common topic of conversation, where people would talk about how "even the older generations are attracted to the use of these technologies."

In terms of particular contextual factors being important in helping individuals adapt to new technologies, evidence has shown that through adequate engagement and empowerment, planning, adequate resources, technical support, and the ability to choose which technology to use, such factors are influential in mainlining the sustainability of uses of technologies.

The evidence that personal characteristics, which are consistently related by individuals who develop practices and uses of technologies over long-time periods, is of particular note. Characteristics such as self-exploration, a willingness to learn new things, personal interest, having a positive attitude towards technology, having an inquisitive nature, and being sensitive to what is out there and what is possible, are all key factors that individuals rely upon to develop uses to suit their needs. This focus on the personal characteristics has been somewhat underplayed by the support community, yet is clearly an important area for future concern.

The integration of technologies with learning, training, and work has been deemed to be important, as it allows individuals to solve problems, to act as a communication tool and

to provide individuals with the means to stay updated. While technologies have increased productivity, efficiency, speed, and performance as well as provided people with a platform of convenience, it is clear that this has arisen as a consequence of their personal interest, drive, and inquisitive concerns.

Approaching the Development of Sustained Uses of Digital Technologies

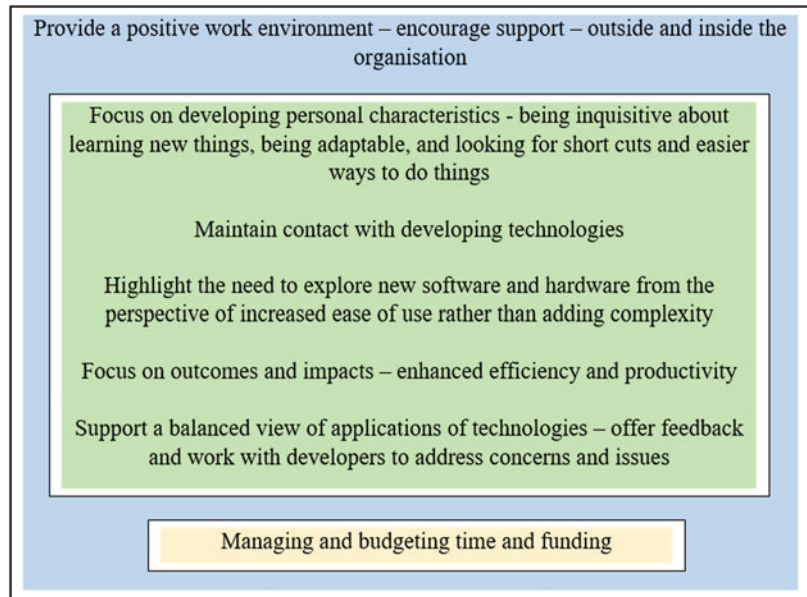
In conclusion, research studies have provided an overview to show that individuals who continue to use technologies for long periods of time are accommodating and accepting of technological advancements and changes. More importantly, the drive behind the acceptance of change is due to a willingness to learn, a sense of curiosity, and a positive attitude towards technology. Thus, sustainability of uses of technologies in communities seems to suggest a positive future in this respect where positive attitudes are positively supported. It is not so much a matter of whether it is a choice for people to accept but is more about adaptability and willingness to accept these technology changes and to explore how they can be of value. In countries studied, individuals with long-term use have learnt to understand the potential and importance of technology, how it can and has benefited their daily lives (whether for personal or work purposes), and how, due to emerging technologies, it has enhanced their lives.

A proposed model for future development of sustained effective and innovative uses of technologies is offered in Fig. 1 (from Passey and Lee 2018). Features of this model relate to factors for successful professional development identified earlier by Joyce and Showers (2002): persistence; acknowledgement of the transfer problem; teaching new behaviors; understanding the importance of the underlying theory; proactive and productive use of peers; and flexibility. Evidence from current studies confirms a continued need to focus on these affective, as well as technological, content, and pedagogic factors.

Research findings suggest that institutions that have focused on providing technical support alone

Sustaining Digital Technology Use in Professional Communities,

Fig. 1 Proposed model for future development of sustained effective uses of technologies. (Source: Passey and Lee 2018)



should rethink their positions. Rather than a single focus on technical support and affordances, evidence indicates that institutions should focus on developing personal characteristics concerned with enquiry and inquisitiveness, highlighting outcome and impact support. This suggests moving away from technical support that focuses on affordances alone, to a focus on outcome and impact support. While there is a clear continued need for essential technical maintenance and implementation to interface with institutional foundations, ensuring infrastructure and accessibility, outcome and impact support for users from a developing personal characteristics perspective is vitally important. It is clear that some support in some institutions is provided in this way, with a distinction being made between infrastructure and network support, and user interface support. However, evidence argues for a focus of user interface support to be on developing creative and innovative personal characteristics that can be applied to technologies. There is clearly a need for institutions and individuals to consider the growing importance of developing digital agency at a personal level (Passey et al. 2018).

Cross-References

- Different Methodological Approaches to Considering the Adoption of ICT
- Situative Perspective and Determinants of Technology Acceptance in Educational Technology
- Teacher Education and Professional Development for Technology Integrated Teaching
- Teacher Education, Thinking About ICT

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Syllabus

► Pedagogical Possibilities for the History of Computing

Tablet Computer

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Tablet Computers

► [Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools](#)

Tablet Use in Higher Education

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Synonyms

[Apple iPad](#); [Blackberry playbook](#); [College](#); [Lecture](#); [Samsung galaxy tab](#); [Seminar](#); [Tablet computer](#); [Tutorial](#); [University](#)

Introduction

Over the past two decades, the use of mobile technology devices in the higher education setting has expanded rapidly. Beginning with laptop computers and personal digital assistants, which became widespread in the early years of the twenty-first century, and continuing with smartphones and eventually tablets, these mobile technologies have had a profound effect on the connectivity, research productivity, and study habits of learners, as well as the classroom dynamics, research productivity, and expectations experienced by faculty. The increased use of a variety of information and communication technologies (ICT) among students is documented in Barry, Murphy, and Drew (2015), and this increase in technology use has produced an enormous body of academic literature examining such topics as adoption decisions, implementation strategies, the impact on learning and academic achievement, and student and faculty perceptions; reviews of the literature examining multiple ICT technologies within higher education have been conducted by Baran (2014) and Moreira, Ferreira, Pereira Santos, and Durão (2017), among others. Among the many competing ICT technologies that have become omnipresent throughout higher

education, this chapter examines the use of tablet technology, a relatively new technology which has been growing in popularity.

Although the first consumer-marketed tablet computers were introduced by Microsoft in 2000, the technology did not achieve mass-market appeal until the release of the Apple iPad in 2010. Since that time, tablet technology has, in particular, become a substitute for laptop computers, a technology that had become widespread in higher education in the preceding decade. A study in 2013 by Cassidy et al. (2014) conducted at an American University found that 33.6% of students were by that point using tablets and 87.5% of students were interested in using one for their studies.

This interest among students was a driving force for numerous universities mandating the use of tablets in specific classes or programs. As a result, many higher education institutions made rapid changes to their systems in an attempt to adapt and embrace the introduction of tablet technology. However, bureaucratic layers within these organizations can prove to be cumbersome and slow down the establishment of new cultures, pedagogy, and structures. Ideally, organizations should proactively plan change interventions to improve organization effectiveness and the well-being of individuals within the organizations. In practical terms, this involves subject matter experts identifying key priorities and offering suggestions that then guide an organization through the change process (Nielsen 2011). Normally, these plans would involve input from key stakeholders, and the formation of an action plan developed after several in-depth levels of analysis, which include environmental factors, organizational culture and systems, leaders, individuals, and respect for interwoven processes (Mintzberg 2011; Wardley et al. 2014). During this planning stage, students and practitioners would be considered significant players in the implementation of new initiatives, and their insights would be incorporated. This process can take time and does not always keep up with demands for the latest forms of technology. Within institutions, policies, and systems are established to reinforce the organization's culture and increase efficiencies. When trying to move

quickly to implement a change process that will impact every aspect of the organization, a whole new set of organizational goals, policies, and processes is necessary. Unfortunately, when dealing with established organizational cultures, moving too fast can create barriers to the change process, including organizational and individual resistance and system failures. Many of the early adopters of tablet technology faced these limitations. Some of these "growing pains" are identified below, but these types of learning tools, when properly implemented, can offer opportunities to advance university graduates' skills, preparing them for today's technology-driven workplaces. The experiences of students and faculty in tablet programs have produced a large and growing literature that forms the basis for this chapter.

Several themes have emerged in the study of tablet technology including the development of implementation strategies that can be replicated; the impact of the technology on student academic performance; student perceptions of, and satisfaction with, the device; and faculty perceptions of the technology. While the majority of studies have used the Apple iPad (e.g., Lee (2015) review, 18 studies specifically examining the use of the iPad in teaching and learning), some studies have examined competing tablet technology such as the Microsoft Surface Pro (Percival and Claydon 2015). In many cases, the findings examined in this chapter are generalizable to a broad range of tablet technologies, and therefore, in the following sections, specific tablet models are mentioned only when results are applicable to that specific model. The purpose of this chapter is to inform stakeholders about the driving forces behind the implementation and acceptance of tablet technology in higher education and guide them, so they can overcome resistance to adoption.

Faculty Experiences with Tablet Technology

Individuals resist change for many reasons including a lack of aptitudes or knowledge, a perception that there is no personal gain, fear of looking foolish, and a lack of trust in those in charge

of the change efforts. These barriers to change, experienced at the individual level, impact group dynamics and the organization overall. Many of these points of resistance have occurred during the introduction of tablet technology in university classrooms.

Many faculty who have adopted the technology have expressed positive perceptions of its value as an education tool (e.g., see Dennen and Hao 2014; Drouin et al. 2014). Nevertheless, resistance to a tablet program has been found among some faculty members who felt that having to redesign their course curriculum to integrate the technology infringed on academic freedom (Mang et al. 2017). Additional faculty concerns have been uncovered by Souleles, Savva, Watters, and Annesley (2017) who find that faculty are weary of the potential of the technology to distract students in class, although Mang and Wardley (2012) show that tablets are potentially less distracting than other common classroom technologies. Souleles et al. (2017) have also reported that faculty were concerned with the time investment necessary to become familiar with the device and the time investment required to select appropriate software applications and devise methods for their integration, and some were unsure about the learning benefits of using tablets.

Among faculty who have adopted the technology for use in their classes or programs, common uses of the tablets include direct connectivity with students, annotating student reports, conducting student assessments, and presenting or demonstrating the course content (DiVall and Zgarlick 2014). However, as the current generation of tablets requires a wired connection to a projector, the adoption of the tablet for presentation purposes continues to limit faculty to a stationary position within the classroom, and some faculty have reported preferring wireless projection technology so that they can move around the classroom with their tablets rather than being tethered to a projector/podium (Percival and Claydon 2015).

Nevertheless, beyond the impact on teaching, the implementation of a tablet program has created a new research trajectory for participating faculty; many of those who have adopted the

technology have begun to undertake scholarly work including conference presentations and the production of peer-reviewed publications regarding the technology and its implementation (Drouin et al. 2014). The many trials, reflections, and recommendations of these scholars have contributed immensely to the compilation of this chapter.

Student Perceptions of Tablets in Higher Education

A major theme of the literature exploring tablet use in higher education has been an examination of student perceptions of, and satisfaction with, the device. Robinson and Burk (2013), Rossing, Miller, Cecil, and Stamper (2012), Mang and Wardley (2013), and Wardley and Mang (2015) have all found that students perceive the technology very positively when used in class; as well, Hahn and Bussell (2012) have reported positive perceptions among first-year students regarding both in-class use and use of tablets outside of class. However, some students have been unsure about whether tablets provide any educational benefit beyond what is available with competing technologies such as laptop computers (Kinash et al. 2012).

Common uses for tablets among students include note taking (van Oostveen et al. 2011), reading electronic textbooks (Weisberg 2011) and magazines (Wang et al. 2016), exploring material related to the course content, and completing quizzes and assignments (Young 2014). In particular, Percival and Claydon (2015) have found that students believe the ease of taking notes and the ability to use electronic textbooks rather than carrying around multiple physical books are key advantages of tablets. However, Weisberg (2011) has found that the proportion of students who prefer to use a tablet as a secondary source of course content, such as reading an electronic textbook, and prefer to also have a traditional textbook is higher than the proportion of students who prefer the tablet as their primary source of course content and textbook; there is thus heterogeneity in views among students regarding the device, and not all perceptions have been positive.

Despite the noted advantages, students have listed several disadvantages of using tablets in class including the small screen size and potential for software incompatibility (Percival and Claydon 2015), a dislike of typing on the tablet screen compared to a computer keyboard (Fischman and Keller 2011; Wieder 2011; Christiansen 2015), and a constant reliance on wireless connectivity to make full use of the device's features (Hashim 2014). Students have also expressed concern with the potential for distraction in class (Young 2014; Percival and Claydon 2015), a serious issue given that other mobile technologies such as smartphones and laptops have been shown to cause distraction and lead to off-task behaviors, such as viewing non-course-related content and social networking, which negatively impacts academic performance (see, e.g., Wood et al. 2012; Junco 2012; Junco and Cotten 2012). Nevertheless, Mang and Wardley (2012) have found that the use of a specific tablet, the Apple iPad, which lacked the multitasking capabilities of laptops and some other tablet devices, significantly reduced off-task behaviors including social media and instant messaging usage compared to the use of laptop computers in class. But a better strategy than relying on the device to restrict unwanted behavior is to demonstrate to students how its correct use will benefit them as more recent changes in that technology to improve multitasking ability may have diminished its usefulness in regard to distraction mitigation. More research on the degree of distraction caused by tablets versus the distractions caused by other devices is needed at this time.

With the introduction of tablets, students have reported that they found the class more interesting (Young 2014) and that the technology helped to create a sense of community and provided students with greater confidence to share ideas with their peers (Wakefield and Smith 2012) and improved students' general satisfaction with their instructor (Wakefield et al. 2018). Overall, students have, in many cases, responded very positively to the adoption of tablets in their classes. Although the adoption process is not without its challenges, students' enthusiasm for

the device (see, e.g., Cassidy et al. 2014) provides a solid foundation on which to build a successful tablet program. Mang and Wardley's (2012) recommendation to manage student expectations through careful explanation of the purpose and benefits of the technology is one strategy to encourage positive student reception. In addition, Minty-Walker, Wilson, Ramjan, and Glew (2017) recommend the creation of a training program for students on how to use the device, noting that effective advanced training is necessary in order for the device to be used to its full potential as many students may come into a tablet program with only a basic knowledge of the device and may not have time to explore its full functionality on their own. In light of student difficulties in adapting to the device noted by Fischmann and Keller (2011), a well-crafted training program that orients students and prepares them to use the device in class should be expected to improve students' perceptions of and enjoyment from using the tablet.

Academic Impact of Tablet Technology

Student perceptions of using tablets in class have generally been positive; however, of chief concern to faculty and institutions is whether or not the technology has positive academic benefits for students. Not all studies have found significant academic benefits to tablet use; van Oostveen, Muirhead, and Goodman (2011) have compared tablet users to laptop users and found that students using tablets did not demonstrate meaningful learning beyond that achieved by laptop users, indicating that, from a learning perspective, the technologies may be close substitutes. As well, Scibora, Mead, and Larson (2018) have found that tablet users had lower engagement and lower attainment of course objectives than nonusers, a result which contrasts with Wakefield et al.'s (2018) and Wilkinson and Barter's (2016) findings; however, Scibora et al. (2018) found that both tablet users and nonusers perform similarly on graded assessments. At the time of writing, no study has yet demonstrated any meaningful negative

academic impact from tablet use, whether compared to other technologies or compared to the absence of technology; much of the existing scholarship has instead demonstrated a variety of avenues by which tablets improve student academic performance.

Tablet use has been shown to motivate students to complete their homework before tutorials and has led to improved student academic performance in the sessions (Wakefield et al. 2018). Adopting tablets has been shown to lead university students to read more often than they otherwise would (Wang, Chiu, Ho, and Lo 2016), an activity often known to improve literacy and academic performance. Furthermore, the ease of access to course material has been shown to increase the amount of time students spend studying as a result of adopting tablets (Hashim 2014; Lazarus et al. 2017). In addition to the academic benefits reaped from extra time spent studying, introducing tablets has also positively affected attendance in classes where the technology is used (Wilkinson and Barter 2016), though this result is perhaps not surprising given the body of research demonstrating students' positive perceptions of the technology. There is thus a multifaceted impact covering numerous academic behaviors, providing significant evidence that the adoption of tablets in higher education is leading students toward greater engagement with their course material.

The improved student engagement resulting from tablet adoption has led to evidence of improvements in graded assessments (e.g., see Wilkinson and Barter 2016; Morris et al. 2016; Raney 2016), as well as skills development. Using tablets in university classes can specifically improve students' oral, written, and graphical communications skills as well as critical thinking abilities (Bagdasarov et al. 2017). Furthermore, improved problem-solving skills among students (Wakefield and Smith 2012), increased student collaboration (Weider 2011), and improvements in organizational skills and research skills (Eichenlaub et al. 2011) have been documented among students using tablets.

In addition to general improvements in student performance, tablets can have a significant

positive academic impact on students with disabilities. Henderson, Gibson, and Gibb (2013) evaluate the use of tablets by higher education students with physical disabilities (sight, hearing, motion, etc.) and with nonphysical disabilities (learning disability, autism spectrum disorder, etc.) and found that tablets can assist such students in a range of academic tasks; in addition, they found that students with physical disabilities strongly preferred tablets over laptop computers, although students with nonphysical disabilities preferred laptops. Ehrlich and Vance (2015) demonstrate how tablets can be used as interpretive devices for students with hearing disabilities and Hendricks et al. (2015) show that tablets can help students who have suffered brain injuries to prepare for a career.

Overall, there is significant evidence thus far to conclude that the adoption of tablets can bring academic benefits from multiple avenues. Improvements in student academic performance have been noted for a range of skills and demonstrated through improved assessment scores. Combined with the positive perceptions students hold of the technology, it is not surprising that initial resistance has lowered and a growing number of faculty are taking interest in the technology and also exhibit positive perceptions of tablet use in higher education.

Implementation Strategies

Despite the many implementation successes described in the literature, numerous difficulties with implementing a tablet program have also been identified; Mang, Brown, and Piper (2017) list resistance among students and faculty to adopting a new technology, the provision of sufficient wireless bandwidth, and the cost of providing tablets to students as barriers to successful implementation of a tablet program. In order to assess the effectiveness of implementing a tablet program in a higher education institution, Hargis, Cavanaugh, Kamali, and Soto (2013) develop a survey instrument which can be replicated at institutions looking to evaluate the success of their own tablet programs.

For faculty and institutions interested in implementing a tablet program, a broad literature now exists providing guidance at each step of the implementation process, from tablet selection, to information technology requirements, to in-class activities. Reflections by early adopters helped to shape the experiences of later trials of the technology, yielding a large array of pedagogical innovations in the humanities, social sciences, and sciences. Early failures of tablet adoption have led to mitigating strategies to tackle both student and faculty rejection, so that faculty and institutions now considering the adoption of a tablet program can experience greater success with its implementation.

Numerous strategies for implementing tablet technology in higher education classrooms have been proposed. While some studies have focused on broad recommendations, others have focused on implementation within specific disciplines. For academic programs which consider mandating the use of a tablet, an implementation strategy is a critical component to ensuring that students find purpose in the device. Early attempts to use tablets, such as those documented in Fischman and Keller (2011), Keller (2011), and Wieder (2011), were not successful as students ultimately rejected tablets in favor of laptops; lessons learned in those trials helped to inform later trials of the technology including Mang and Wardley (2012) which provides some of the earliest general recommendations on the creation of a tablet program in higher education.

Mang and Wardley (2012) provide six recommendations for faculty including knowing the details of the operating system, deciding early how to use the technology in class, working closely with the institution's information technology department, making the tablet an integral component of the class, describing the benefits and features on the first day, and carefully considering the method of tablet distribution to students. Anticipating that some students will experience technical difficulties, they note that it is important for student perceptions of the device that the instructor and the institution be prepared to offer timely advice and assistance. Anticipating that some students may be either unenthusiastic or

openly resistant to the technology, Mang and Wardley (2012) advocate for purposeful and well-explained usage of the device to manage student expectations.

To aid faculty in understanding the benefits and drawbacks of the technology, and in determining how best to make use of the technology in class, Dennen and Hao (2014) develop the M-COPE framework focusing on mobile affordances, conditions, outcomes, pedagogy, and ethics as the key elements in designing a higher education curriculum that incorporates mobile devices. They identify productivity, flexible physical access, capturing and integrating data, and communication and collaboration as chief benefits afforded by the use of mobile devices. They further identify learner preparedness, environmental suitability, time, and disruption of existing learning patterns as key conditions which may impact the successful use of mobile technology. Dennen and Hao (2014) emphasize choosing a pedagogy that supports desired learning outcomes and advise faculty to be aware of potential ethical issues arising from device usage such as socioeconomic conditions affecting the type of device(s) students may have access to.

Numerous pedagogical approaches have been taken when implementing tablets across a course or an academic program for the purposes of improving information literacy; for example, Brooks (2015) recommends using connectivism, a philosophy that emphasizes a learner's ability to form connections between networks of information sources (see Siemens 2005), as a guiding approach to designing information literacy skills building tasks for students using tablets. Such tasks involve searching for and evaluating the usefulness of various types of information. Moore, Black, Glackin, Ruppel, and Watson (2015) use a process-oriented guided inquiry learning (POGIL) model to integrate tablets into team-based exercises in which students develop information literacy skills by performing tasks designed to locate, use, and evaluate information. Mang, Brown, and Piper (2017) describe the co-implementation of a tablet program with a "Common Book" program, another recent

pedagogical innovation that integrates a single work of fiction or nonfiction into a variety of courses and/or extracurricular activities within an institution. They describe how the tablet program can be combined with a Common Book program to improve students' information literacy skills across a range of categories identified by Doyle (1992) including using tablets to search for information related to themes presented in the book and sharing the information with fellow students.

Additional general suggestions for the implementation of tablets into higher education classrooms include the use of quick response (QR) codes to index course content, whether stored on a learning management system or linked to an external resource, so that students with a tablet can quickly navigate to relevant information (Husbye and Elsener 2013), and the development and distribution of tablet-formatted lecture slides which specifically include space for students to handwrite additional notes on the tablet during the lecture as well as the use of in-class electronic quizzes (Mang and Wardley 2012).

Much work has been done to provide discipline-specific recommendations for tablet implementation. In the field of teacher education, Nguyen et al. (2016) develop a three-pronged approach to using tablets to train aspiring teachers: enhancing personal productivity, increasing collaboration in coursework completion and between faculty and students, and applying these new technology-based skills when teaching children. Furthermore, they provide an overview of various accessibility features of a tablet device, including available support systems for students with vision, hearing, physical, or cognitive disabilities, which have implications both in the instruction of aspiring teachers and for the future careers of teaching graduates using the technology to instruct youths. Marín et al. (2016) recommend a range of activities for teacher education programs including communication, collaboration, teamwork, video and photo editing, music creation, media playback, and social networking services that can be accomplished using tablets; they note that these activities impart new

skills to aspiring teachers and improve the learning experience.

Within the sciences, Rosenthal and Eliason (2015) discuss the implementation of tablets in a university physical health and education program; they develop a "pedagogy wheel," a graphical display based on Bloom's taxonomy (Bloom et al. 1956) which maps learning objectives in physical health and education to specific mobile applications that can be used, and specific activities that can be performed, on a tablet. Rosenthal and Eliason (2015) discuss methods to pair assessment with specific learning objectives across a range of physical health and education classes making use of tablet technology and specific mobile applications, particularly in laboratory exercises. Hesser and Schwartz (2013) also describe potential uses for tablets in laboratory classes; they recommend specific mobile applications that can be downloaded to the tablet for learning management, document storage, and chemistry simulation in order to eliminate all paper-based materials within a university laboratory class. Additionally, Morris, Lambe, Ciccone, and Swinnerton (2016) make recommendations for specific activities and mobile applications for tablet devices in neuroanatomy laboratory sessions. Furthermore, Stone (2016) describes implementing tablets in computer science classrooms including activities such as building flowcharts, writing computer code, and creating information products based on collaborative research.

Within the humanities and social sciences, Brewer, Begleiter, Anderson, and Issacs (2015) discuss how to use tablets in a political science class by encouraging students to use social media to research and connect with political campaigns. Gabarre, Gabarre, Din, Shah, and Karim (2014) show that tablets can be used to assist students with translation exercises in a foreign language class, while Brown, Castellano, Hughes, and Worth (2012) and Gitsaki and Robby (2014) demonstrate how tablets can be used to teach English. Marín et al. (2016) discuss a variety of uses for tablets in music education such as recording, editing, and processing exercises.

Once a decision has been made to adopt tablets across a program, Drouin, Vartanian, and Birk (2014) recommend the development of a community of practice, an information sharing network among faculty; they design and explain how to implement a community of practice model to assist faculty through the adoption process, emphasizing regular meetings of both small and large groups of faculty who can share their experiences with the technology, offer suggestions on in-class use, offer problem-solving advice, and determine best practices for using the device.

These early studies offer some ways to overcome resistance to change at the organizational level through effective implementation strategies. Communicating a clear vision of why the change is needed and what direction the change will take can allow faculty, students, and administrators the opportunity to embrace the introduction of tablets. Offering champions that can help to lead others during the change process can let faculty and students know specifically what is expected of them and provide training and support for any identified gaps in knowledge or skills. Establishing a system of incentives for students and faculty can also be helpful, so faculty and students see the benefits of learning the skills needed to succeed. Identifying the best way and timing to make the change must vary according to the realities of the workplace. Evaluating and modifying resources and supports based on feedback are also an effective way to remove barriers.

Conclusion

The use of tablet technology in higher education offers the potential to strengthen students' learning transfer and workplace technology-based competencies. Implementing tablet technology programs has recently emerged as a valuable way of developing these competencies. Improvements in information literacy, collaboration, and research skills have all been documented. Furthermore, tablets have been

shown to improve academic engagement among students. Nevertheless, the complexities of structuring and delivering a tablet program are noteworthy as are the concerns of faculty, students, and administrators who are involved in supporting these programs.

Success in implementing a tablet program is not guaranteed. Despite generally high rates of satisfaction with the device among both students and faculty, it is clear from examining both the earlier (failed) trials and more recent successful trials of the technology that strong preparation for the implementation of the device is a key prerequisite to success. Without the removal of barriers during the implementation process, tablets will not be used to their full potential. Effective curriculum design with a clear strategy for using the device in class, clear explanation of the device's purpose, and out-of-class technology support are common features of successful tablet programs. When the device has been seen to be a hindrance, when its purpose has not been fully explained, and when useful activities to perform with the device have not been designed, tablet implementation has proven less successful. The key issue of off-task distraction identified by both students and faculty is one significant drawback to technology use that needs to be carefully considered during implementation.

As the use of tablets in higher education has expanded, new suggestions for implementation in the humanities, social sciences, and sciences have emerged, providing new avenues for further experimentation and scholarship. The positive benefits accruing to tablet use have been well documented leading to a further proliferation of tablet programs at higher education institutions.

Cross-References

- ▶ [Assisting People with Physical Disabilities through Technology](#)
- ▶ [Assisting People with Vision Impairments Through Technology](#)

- [Assisting Students with Learning Disabilities through Technology](#)
- [Collaboration and Social Networking](#)
- [E-Books Among Students, Advancements in Higher Education](#)
- [Information Technology and Assessment](#)
- [Learning Strategies and Achievement of IT Students in Higher Education](#)
- [Mobile Computing and Mobile Learning](#)
- [Mobile Learning](#)
- [Mobile Learning and Ubiquitous Learning](#)
- [Social Networking in Higher Education](#)
- [Students' Computer Literacy and the Use of Tablets in Upper Secondary Schools](#)
- [Teacher Education, Thinking About ICT](#)
- [Technology Enhanced Learning](#)

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Teacher Education and Professional Development for Technology Integrated Teaching

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This entry describes the characteristics of professional development programs (PD) to enhance teacher educators' (teachers of pre-service teachers) knowledge of technology-integrated teaching which subsequently facilitates their effective use of technology in the teaching in initial teacher education institutions. There are challenges with using technology in teaching, but relevant PD can help teacher educators to overcome these challenges for the effective use of technology in teaching. The description is drawn upon data from an intervention study involving designing and handling PD to assist mathematics teacher educators in integrating technology in their teaching and illustrating the characteristics of effective PD for teacher educators in tertiary settings. The entry is organized in five sections. It begins with a description of the importance of technology in higher education followed by an illustration of teacher education that highlights the challenges for technology-integrated teaching. The third section illustrates the characteristics of effective PD for technology-integrated teaching in initial teacher educations. The fourth section suggested the characteristics of effective PD programs for teacher educators and implications for preparing pre-service teachers. The conclusion summarizes the findings presented in this entry. Some of the study papers referred to concerned PD programs for school teachers that were included because of their relevance to teacher educators at initial teacher education

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institutions. The following section highlights the importance of technology in higher education.

Importance of Technology Use in Teaching

Using technology in teaching can lead to significant positive outcomes for student learning and also bring significant benefits to teachers (e.g., Ayub et al. 2010; Bu and Haciomeroglu 2010). This has motivated university, college, and school teachers to integrate technology into teaching to achieve better learning outcomes. Technology can support constructivist pedagogy, as students use technology to explore and reach an understanding of concepts (e.g., Bu and Haciomeroglu 2010). Technology-based learning environments can provide opportunities for active learning that can enable students to perform at higher cognitive levels, support their effective learning, and promote scientific inquiry and conceptual change. For such purposes, a wide range of virtual educational environments and applications are available that offer a variety of possibilities for both students and teachers. Increased availability of technology resources, however, does not guarantee increased rates of effective integration of technology (Getenet et al. 2016; Hew and Brush 2007); instead, the integration of technology tools into teaching demands specific skills of teachers that can be enhanced through professional development [PD] (Niess 2011). In addition, there are various factors which can inhibit technology's practical use in teaching. The following section describes these factors.

Teacher Education and Challenges for Technology-Integrated Teaching

It is a common misconception that access to technology alone motivates teachers to apply it in their teaching. On the contrary, studies (e.g., Getenet et al. 2016; Hennessy et al. 2010) have shown that among the most significant barriers to the use of technology are teachers' motivation and confidence, technological literacy and confidence

levels, pedagogical expertise related to technology use, and understanding of the role of the teacher when integrating technology. Teachers need to learn how to use technologies in their teaching. A lack of technical support of expertise in the schools and teachers' lack of expertise in using technology are reportedly the most prominent factors hindering teachers' readiness and confidence in using technology (Looi et al. 2008). While there were some notable exceptions to this generalization, it seemed that computer laboratories in schools and higher educational institutions stand idle for much of the time (Tella et al. 2007), but as more classrooms become technology-rich environments, it is less likely that teachers will perceive the lack of access to technological resources as a barrier to effective technology integration.

The other major barrier to effective technology integration is teachers' knowledge of technology and pedagogy extended into the domain of teaching with technology that is teachers' technological pedagogical and content knowledge [TPACK] (Koehler and Mishra 2009). The idea of pedagogical content knowledge combined with technical knowledge is likely to take the place of lack of technology resources as the primary determinant of the extent to which technology is integrated into teaching (Niess 2011) because teaching effectively with technology requires teachers to have TPACK. Niess (2011) emphasized the importance of teachers having integrated knowledge of technology, pedagogy, and content for effective teaching through technology. The ability of teachers to coordinate content, pedagogy, and technology depends mainly on the way teachers were taught to integrate technology into teaching and how these components are acquired in PD sessions (Koehler and Mishra 2009). Hence, insufficient PD to support teachers to integrate technology is another barrier, which has implications for school teachers as well as teacher educators (teachers of pre-service teachers), including the ongoing need to equip them with the necessary skills to integrate technology in teaching.

Along with teacher educators having the skills and knowledge to integrate technology in their own teaching of pre-service teachers, they also

need to prepare pre-service teachers to integrate technology in their teaching using a variety of different approaches. It is not sufficient to teach the next generation of pre-service teachers in the ways their educators were taught. Pre-service teachers must encounter the effective integration of technology in the normal course of their learning at initial teacher education institutions, particularly as technology is becoming increasingly available in schools. Albion, Tondeur, Forkosh-Baruch, and Peeraer (2015) recommended that teacher educators become familiar with what to do with these new tools and digital media and create meaningful learning opportunities for pre-service teachers even though they themselves have not experienced such opportunities. Researchers such as Valtonen et al. (2015) and Tondeur et al. (2016) have made many recommendations about effective ways of supporting pre-service teachers to teach using technology, and ensuring that pre-service teachers see technology being modelled by educators in their own teaching is one means. When teacher educators act as models, pre-service teachers can see the importance of developing and using technology-based lessons in their own teaching (e.g., Ertmer and Ottenbreit-Leftwich 2010). Recent trends in teacher education have emphasized the importance of learning with technology rather than learning about technology (e.g., Tondeur et al. 2016; Valtonen et al. 2015). This means that teacher educators need to use technology to enhance pre-service teachers' learning of mathematics rather than teaching isolated skills using specific computing applications (e.g., word processing, database, spreadsheets, or hypermedia) or merely learning a specific programming language. Drent and Meelissen (2008) found that a teacher educator who uses technology for the enhancement of the learning process of pre-service teachers shows those pre-service teachers how technology can be used in their future teaching. Nevertheless, many teacher educators lack the knowledge needed to do so.

One way of improving teacher educators' skills in integrating technology in their teaching is through PD programs from which teacher educators can gain an understanding of the use of

technology and ways to change their roles and practice in their teaching accordingly. Emphasizing teacher educators' PD is a key factor in tertiary education to effectively use technology to enhance teaching and learning (Hennessy et al. 2010). Drent and Meelissen (2008) showed that participating in ongoing PD helps teacher educators to acquire the knowledge needed to integrate technology in their teaching.

Studies investigating PD programs aimed at the use of technology in teaching have indicated that such programs are often focused on the acquisition of basic skills in the use of technology and typically taken place in training centers in the form of seminars (e.g., Voogt et al. 2012). With few exceptions, therefore, PD programs for technology integration in teaching lack adequate duration, continuity, and pedagogical direction (Schibeci et al. 2008). In addition to the need to focus on the pedagogical use of technology, there is a gap in supporting teachers in relation to technology use in teaching in ways that are based on subject-specific content and pedagogies (Voogt et al. 2012). The following section describes the characteristics of effective PD programs that focus on integrating technology in teaching.

Characteristics of Effective Professional Development

Although PD programs are essential to enhancing teacher efficacy, they are often organized in traditional and prepackaged forms. However, traditional models of PD have not been particularly successful in helping teachers to find ways to integrate technology into their teaching, and teachers are not comfortable with such PD programs. In recent years, effective PD has been considered a long-term process that includes regular learning opportunities and experiences planned systematically with the involvement of participants. Traditional PD programs have been criticized for being ineffective because they are often organized as fragmented and superficial workshops or seminars that do not allow for participants' involvement in the design process. On the other hand, PD programs which emphasise on

the importance of involving participants in a PD program design process, consider team formation, encourage collaboration and value the role of facilitators are increasingly regarded as effective PD programs (Getenet 2015).

In addition, more effective PD program strategies are designed to move beyond the acquisition of basic technology skills to conduct technology-focused lessons and the pedagogical aspects of technology use and eventually to help teachers to adopt appropriate technology integration in their teaching. Technology-related PD programs need to be school-based, collaborative, and continuous (Schibeci et al. 2008; Hea-Jin 2007). Such PD programs are likely to help teachers at any level exploit additional learning opportunities afforded by technology and begin to make fundamental changes to their pedagogy (Schibeci et al. 2008) because they are supportive of acquiring the appropriate skills for using technology in teaching (Kalogiannakis 2010). Schibeci et al. (2008) argued that the complex process of preparing teachers to use technology is best supported by PD programs that focus on pedagogy and adult learning rather than short-term training. In addition, O'Bannon and Judge (2004) suggested that PD programs can be more effective when viewed from a whole school approach, which encourages change over time.

According to Lavonen et al. (2009), informal discussions in small groups and continuous support are vital aspects of effective PD in general. Similarly, McKnight, O'Malley, Ruzic, Horsley, Franey, and Bassett (2016) emphasized the importance of group formation, collaboration, and ongoing practices as essential components of effective PD programs. In addition, rehearsal of classroom practices, active involvement of facilitators, and thoughtful and informed decisions about the context are essential aspects of effective PD programs. Van den (1999) suggested three advantages of scaffolding a PD program with exemplary materials which are creating a clear understanding of how to translate the new teaching into classroom practice, provide support for the execution of technology-integrated lessons, and stimulate teacher educators to practice the intended teaching approach.

Hea-Jin (2007) developed a model of an effective technology-related PD program to enhance teachers' conceptual understanding and pedagogical strategies and the effective use of technology. The design of that study incorporated four essential components of effective PD programs: systemic support, knowledge-building workshops, classroom implementation and application, and building a team. Hea-Jin argued that in order to be effective, teachers need sustained and ongoing PD to learn, analyze, and reflect on new concepts and the use of technologies for effective student learning. Real classroom experience, collaborative work, and systematic support for effective PD are also important aspects (Valtonen et al. 2015).

Recent studies, therefore, underpin a paradigm shift in PD program strategies from traditional one-stop training, workshops, and the like toward more collaborative models. Traditional PD programs, in general, have been criticized for resulting in the surface-level implementation of instructional principles as opposed to deeply rooted changes in practice. In contrast, collaborative models of PD tend to engage teachers in joint inquiry about teaching as a means of shifting practice. Furthermore, collaboration can be realized through the formation of teams of teachers engaged in successful collaborative PD (Looi et al. 2008).

PD Program Strategies and Teacher Educators

Despite the wealth of commentaries on teacher education programs, there is little empirical research focused on teacher educators themselves (Beswick et al. 2012; Beswick and Goos 2018; Ottenbreit-Leftwich et al. 2012). A question seldom discussed in the literature concerns the extent of what teacher educators need to know in order for pre-service teachers to learn from them. Although teacher education is considered necessary for the quality of teachers, very little is known about the professional quality of teacher educators. For example, Beswick and Goos (2018) showed that mathematics teacher educators' knowledge is under-researched area, but

their knowledge is an indicator of pre-service teachers' quality. Hence, there is a need to study teacher educators and the role of the teacher educators and to rethink the kinds of knowledge and skills teacher educators ought to have for effective teaching of pre-service teachers. There are few studies on PD programs offered to teacher educators with a few of these focused on the PD program needs of newly appointed teacher educators, the effectiveness of PD program activities carried out for the teacher educators, and the difficulties they experience (Kabakci et al. 2010). A desirable professional competency of teacher educators that has been identified is the ability to model explicitly for pre-service teachers the thoughts and actions that underpin their teaching approaches (Loughran and Berry 2005). Hence, there is a need for teacher educators to participate in PD programs to help them effectively use technology in their teaching and to enable pre-service teachers to learn about using technology from teacher educators practice.

Teacher educators need ongoing PD programs in the effective use of technology in order to keep up with the changes and developments in technology and to be able to model appropriate use of technology for teacher candidates (Kabakci et al. 2010). Little is known about how best to assist teacher educators in using technology to influence pedagogy and content in a particular context. In a review of PD programs on technology use in teaching (Getenet et al. 2016), it was suggested that PD programs for teacher educators emphasize the interplay of technology, pedagogy, and content knowledge for effective teaching with technology. The availability of many different technologies that can facilitate teaching and the challenge of keeping up to date with new emerging technologies means it is unrealistic to attempt to equip teacher educators in relation to all available technologies and pedagogies. Nevertheless, there is a range of pedagogical practices that can facilitate the learning of students (e.g., problem-solving, inquiry learning, etc.). PD programs that focus on these strategies can enhance teacher educators' knowledge for teaching with technology and help them design appropriate pedagogy and technology for use in their teaching. Teacher

educators in initial teacher education institutions require PD programs which are flexible to suit for their busy time schedules. The following characteristics of the PD program developed by Getenet (2015) are relevant to teacher educators generally. They are drawn from an intervention study involving designing and developing PD to assist mathematics teacher educators in integrating technology in their teaching in tertiary settings.

Context-Based

Understanding context can help PD program designers to gain a better picture of teacher educators' needs and suggest context-based PD program guidelines (Vangrieken et al. 2017). Context is a collection of factors that can influence the design of the PD program for a particular group or be delivered in a particular environment (Smith and Ragan 2005). A context analysis plays a vital role in providing rich data for designing real examples, practical content, and scenarios (Vangrieken et al. 2017). According to Wood et al. (2011), for example, considering and analyzing the context in which the PD program is to be implemented is an essential component of an effective PD program. Smith and Ragan (2005) suggested three themes in analyzing the context: learner analysis (teacher educators), learning context analysis, and learning task analysis. Learners' characteristics and characteristics of the learning context (the physical place in which the PD will be delivered) can be used to suggest the learning tasks which constitute a PD program (Smith and Ragan 2005). Table 1 shows the three aspects of context analysis along with guiding issues to be considered as suggested by Smith and Ragan (2005) for effective PD program design.

According to Smith and Ragan (2005), the analysis of learners' characteristics is an important aspect of instructional design in general and PD program design in particular. In particular, the analysis of learners' specific prior knowledge is a crucial feature.

As part of the context analysis, the environment in which the PD program is to be conducted should be analyzed to gain insight into the existing conditions in relation to the PD program. According to Smith and Ragan (2005), the

Teacher Education and Professional Development for Technology Integrated Teaching, Table 1 Context analysis aspects and guiding issues

Context (Smith and Ragan 2005)	Guiding issue (Smith and Ragan 2005)
Analyzing the learners	Learners' general characteristics Learners' prior knowledge Learners' age Learners' beliefs toward the subject matter Learners' preferences, attitudes, interest
Analyzing the learning context Need assessment	Determine whether there really is a problem Determine whether the cause of the problem is related to educators' performance due to a particular problem Determine whether the solution to the achievement/performance problem is learning Determine whether the instruction for these learning goals is currently offered
Describing the learning environment	Are there existing curricula into which this piece of design must fit? What hardware is commonly available in the potential learning environment? The characteristics of the classes and facilities that will use the new PD program results The characteristics of the school system
Learning task analysis	Write learning goals Conduct an information-processing analysis of that goal Conduct a prerequisite analysis Determine the type of learning of the prerequisites Write learning objectives for the learning goals

analysis of the learning context involves two major components including the substantiation of a need for the PD program and a description of the learning environment in which the PD program will be implemented. After understanding the learning context and the learner context, the next step is to identify an appropriate PD program to address the context. Smith and Ragan (2005) indicated that the principle steps in performing a learning task analysis are, for example, to write learning goals, conduct a prerequisite analysis and determine the type of learning of the prerequisites, and write learning objectives for the learning goals.

In summary, investigating the characteristics of context for a PD program design process makes the content concrete and realistic and makes it more likely that the PD participants will understand how their learning can be applied in the classroom teaching.

Team Formation

Team formation is considered a suitable PD program strategy (Looi et al. 2008) on the assumption that knowledge is dynamically constructed as teachers conceive of what is happening to them, talk, and reflect. Group activities have been shown

to benefit teacher educators by providing opportunities to share ideas with colleagues (McKnight et al. 2016). Team formation in PD programs is effective when four critical characteristics are present and contribute to the proper functioning of the team in supporting members' efforts to integrate technology into their teaching. The team formation characteristics are active involvement, collaboration, positive attitude and a clear and shared vision of the team (Vangrieken et al. 2017).

Team formation can be used as a strategy to encourage teacher educators to collaborate with colleagues on an ongoing basis and adapt the PD program to suit participants' particular schedules. Studies (e.g., Looi et al. 2008, Lavonen et al. 2009) have suggested that the formation of small teams is helpful in supporting teachers to talk and reflect upon what is happening in the classroom on a continuous basis. The collaboration within the teams is particularly enhanced by incorporating them in a PD program as informal component of the PD. Looi et al. (2008) indicated that informal discussion is helpful to dynamically construct knowledge and deepen knowledge while the PD participants talk about what is actually happening in the classroom and can provide teacher educators with the opportunity to share ideas with their colleagues.

Informal and Flexible PD Arrangements

According to Lavonen et al. (2009), an informal discussion in small groups and continuous support are vital aspects of PD. Informal or flexible PD program arrangement, however, has not been mentioned as a characteristic of effective PD programs in these studies. Nevertheless, informal arrangements are an essential feature of a PD program to support teacher educators to integrate technology into their teaching of mathematics successfully. Participating in informal PD perhaps as part of a more structured program is preferred to formal PD program that requires teacher educators to regularly attend large group sessions. PD programs structured around teacher educators' availability and that fit with their own schedules could be the best approach to address teacher educators' tight schedules (Getenet 2015).

Looi et al. (2008) indicated that informal discussion is helpful to dynamically construct knowledge and deepen knowledge while teacher educators talk about what is actually happening in the classroom. In addition, the informal setup can provide the teacher educators with the opportunity to share ideas with their colleagues and thereby create a continuous PD program. The teacher educators are likely to favor of a PD program based on their availability and one which fits with their own schedules. Three advantages of informal PD program arrangements are:

- It does not require the presence of all teacher educators at the same time.
- It facilitates easy discussions and collaborations with colleagues.
- It creates a feeling for the continuous PD program on participant teacher educators.

This arrangement facilitated the teacher educators' participation based on their available time, providing continuous involvement without being physically together (Getenet 2015).

Focus on Pedagogical Use of Technology

Studies suggest that effective PD programs move beyond the acquisition of basic technology skills (e.g., Hea-Jin 2007; Schibeci et al. 2008) to focus on the pedagogical use of technology. The lack of

PD focused on pedagogy associated with technology use can hinder teacher educators from integrating technology into their teaching. In addition to the need to focus on the pedagogical use of technology, there is a need for PD designed to support teachers to use technology in teaching in ways that are based on subject-specific content and pedagogies (Voogt et al. 2012). PD programs which focus on how technology, pedagogy, and content interplay in a classroom context for effective teaching are essential for using technology-integrated teaching. An emphasis on the pedagogical use of technology can facilitate teacher educators' creation of relationships between pedagogy, the selected content or concept, and the technology, thereby enabling them to apply their learning in their teaching. Such PD programs are imperative for developing an understanding among the teacher educators of technology integration with the pedagogy and content.

Exemplary Materials

Preparation of the exemplary material can provide the teacher educators with a point of reference to design their own technology-integrated lessons. According to Van den Akker (1999), there are three advantages of including exemplary material when designing a PD program. These advantages are (i) creating a clear understanding of how to translate the new teaching approach into classroom practice, (ii) providing a solid foothold for the execution of technology-integrated lessons that resemble the intended objectives, and (iii) stimulating teacher educators to practice the intended teaching approach. Exemplar material created and provided as part of the PD program can develop teacher educators' awareness of the possible use of technology in their teaching and the importance of their use of technology as a model for technology-integrated teaching.

Conclusion

Supporting teacher educators in technology integration through PD not only can enhance the quality of their teaching but also facilitate the preparation of pre-service teachers to be effective

in teaching with technology. This is because learning to use technology from their teacher educators' teaching was shown to be a more effective way of preparing pre-service teachers to use technology in their teaching than simply learning about teaching with technology. Designing PD programs for teacher educators requires consideration of various factors. This entry has highlighted the characteristics of PD programs that the teacher educators can benefit from not only in order to use technology their teaching effectively but also in order to prepare pre-service teachers to use technology in their teaching. The characteristics of effective PD programs for this purpose are that they are context-based, focus on the pedagogical use of technology, include team formation, are supported by exemplary material, and include an informal setup that can support teacher educators' effective use technology in their teaching.

The emphasis of PD programs on the pedagogical use of technology can facilitate the teacher educators' creation of relationships between the pedagogy, the relevant content concept, and the technology, enabling them to apply them in their teaching.

PD programs with these characteristics are especially relevant to those looking to improve teaching with technology with the teacher educators recognizing that this can influence pre-service teachers to use of technology. They are especially relevant to those looking to improve teaching with technology with teacher educators recognizing that this can influence pre-service teachers to use of technology.

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Teacher Education, Thinking About ICT

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Synonyms

Digital technology; Trainee teachers

Introduction

There is a growing emphasis on digital competence as part of mainstream education, and teachers need to be prepared to teach it. ICT has been included in a growing number of national school curriculums in two main ways. School graduates need to be digitally competent in order to go on to further education or enter the workforce, so ensuring that students have an understanding of how to use ICT to communicate, collaborate, and create in a safe way is a clear part of many curriculums. In addition, digital technologies have been integrated into curriculums as part of teaching and learning of other subject areas in an effort to improve educational outcomes. Teachers, therefore, need to be instructed how to teach ICT but also to use ICT to teach subject content.

Educating student teachers about how ICT can be used in education involves more than

technological know-how. The pedagogical and content knowledge components of ICT in education are arguably more important. In addition, student teachers should not blindly use ICT but be given tools to critically evaluate the educational value of digital activities. Successfully incorporating ICT into education degrees requires student teachers to not only understand why ICT could be used to support learning and teaching across the curriculum but to also experience this (Tondeur et al. 2012). Many teacher educators do not have this knowledge or experience themselves (Tondeur et al. 2012), and current embedding practices range from a transmission lecture approach (didactic) to a combination of transmission and hands-on learning (didactic and constructive) during workshop style tutorials. Employing experiential learning where student teachers are required to learn using ICT themselves is seen as an effective way of including ICT in teacher education.

The Importance of Creating Digitally Competent Teachers

Many assumptions have been made about what digital competence means, the level of competence students and student teachers already have, and how much explicit instruction is required to create a digitally literate society. The idea of the “digital native” (Prensky 2001) persists in universities, as evidenced by the push to move education into online environments. However, while technology is embedded in young people’s lives, their skills are not uniform, and they use a limited range of established technologies (Jones et al. 2010; Margaryan et al. 2011). Completion of school does not necessarily result in uniformly digitally competent students. In Australia, the most recent results of the Australian National Assessment Program indicate that the percentage of Year 10 students reaching proficiency level for digital technologies is concerningly low (52%) and show a statistically significant drop in digital competence across all cohorts of students since testing began in 2005 (National Assessment Program 2014). The drop in the digital competence of school students suggests current methods of educating student

teachers about ICT are not as effective as hoped, with many student teachers not reaching the levels of competence envisaged to deliver the curriculum. Universities are grappling with the most effective way to achieve this. While the best method of embedding digital content in education units is not yet clear, the importance of using considered pedagogical practice when educating student teachers to exploit technology appropriately in their teaching is.

Initial Teacher Education Content

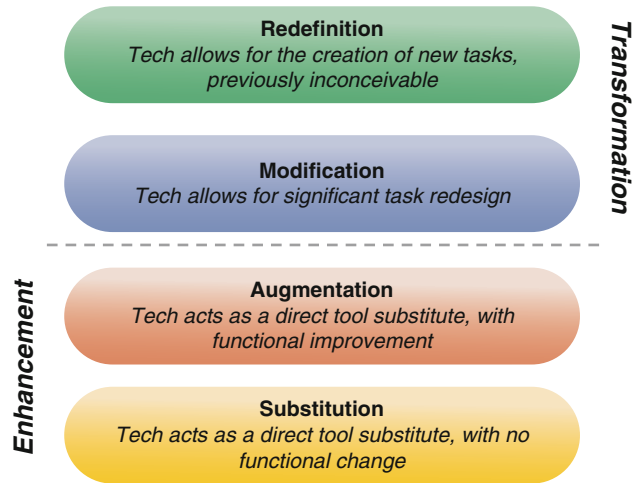
Initial teacher education is responsible for ensuring that student teachers are ready for the complexities of their future workplace (the classroom). Thus, initial teacher is tasked with ensuring student teachers are digitally competent and also preparing them to teach digital competence. This includes not only technological, pedagogical, and content knowledge but the ability to critically assess ICT. Future teachers need to be competent and confident enough to teach ICT and teach with ICT.

Curriculum Expectations

Through curriculum documents, governments around the world have mandated how digital competence and the use of ICT for teaching and learning should be incorporated into the school environment. Student teachers need to be made aware of school curriculums through their teacher training.

For example, in Australia, digital technologies are taught to Australian school students in two ways (Australian Curriculum and Reporting Authority 2018). First, there is a dedicated technologies learning area made up of two strands: design and technologies and digital technologies. Specific examples of the strand include computation thinking and spreadsheets. Second, the curriculum recognizes ICT as a general capability, to be embedded across all subject areas. All teachers are expected to incorporate this general capability in their lessons, for example, using a common digital tool with subject content, such as using Excel to make a graph, improving literacy with

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Fig. 1 SAMR model
(Puentedura 2010, p. 2)



eBooks, or using Google maps to teach map reading skills.

In other countries ICT is represented in the curriculum in a much more straightforward way. For example, Scotland and Canada include ICT across all curriculum areas, while the UK curriculum includes ICT as a separate subject. Interestingly, Japan does not have a strong emphasis on ICT, and in the Netherlands, each school is able to determine how ICT is incorporated into the curriculum. What is clear is that for the majority of countries, integrating ICT in everyday teaching practices is a priority and something that all future teachers will need.

Purposeful Use of Technology

Student teachers also need to be made aware of the research on educational technology. Findings suggesting the effectiveness of using ICT in education are inconclusive (Organisation for Economic Co-operation and Development 2015) and should alert student teachers that careful assessment of the pedagogical worth of digital technologies, and how they are to be used, needs to occur before considering employing them in class. Therefore, student teachers need to be exposed to a number of models which can help them critically assess the usefulness of ICT to deliver specific content. One such model is the SAMR model (Puentedura 2010) which describes four categories of tasks: substitution, augmentation, modification, and redefinition. At the substitution level,

a digital resource is a duplication of the traditional equivalent. For example, a digital textbook that is an exact replica of a paper textbook with no added features. At the augmentation level, there is functional improvement, such as links to videos, extra resources, or augmented reality. Modification suggests that the digital resource has been redesigned significantly, for example, the textbook operates as a blog and students from around the world can add comments. Redefinition suggests a task that has been designed in such a way that it could not be done without technology, for example, students create an original online textbook, including videos, based on their own research (Fig. 1).

Digital Competence

Digital competence is more than just being able to turn on a computer. In addition to knowing how to operate ICT tools, there are many other facets of digital competence. Ferrari (2013) states that people need to have the following five key competencies in order to live within a digitally saturated twenty-first-century world.

Information:	Identify, locate, retrieve, store, organise and analyse digital information, judging its relevance and purpose.
Communication:	Communicate in digital environments, share resources through online tools, link with others and

- collaborate through digital tools, interact with and participate in communities and networks, cross-cultural awareness.
- Content-creation:** Create and edit new content (from word processing to images and video); integrate and re-elaborate previous knowledge and content; produce creative expressions, media outputs and programming; deal with and apply intellectual property rights and licences.
- Safety:** Personal protection, data protection, digital identity protection, security measures, safe and sustainable use.
- Problem-solving:** Identify digital needs and resources, make informed decisions as to which are the most appropriate digital tools according to the purpose or need, solve conceptual problems through digital means, creatively use technology, solve technical problems, update one's own and others' competences. (Ferrari 2013, p.4)

As Koehler and Mishra (2009) point out, “teaching is a complicated practice that requires an interweaving of many kinds of specialized knowledge” (p. 59). It is not enough for student teachers to be digitally competent themselves; teacher education programs should provide student teachers with an understanding of the curriculum content, the pedagogical understanding to employ considered and purposeful use of technology for learning and teaching, as well as exposing them to a wide range of digital experiences. This is what Koehler and Mishra (2009) refer to in the TPACK model. This model, which has become an essential framework to guide ICT initial teacher education, suggests that

teachers need an understanding of how content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) converge to form technological pedagogical content knowledge (TPACK) in order to effectively incorporate technology into education (Fig. 2).

Social Considerations

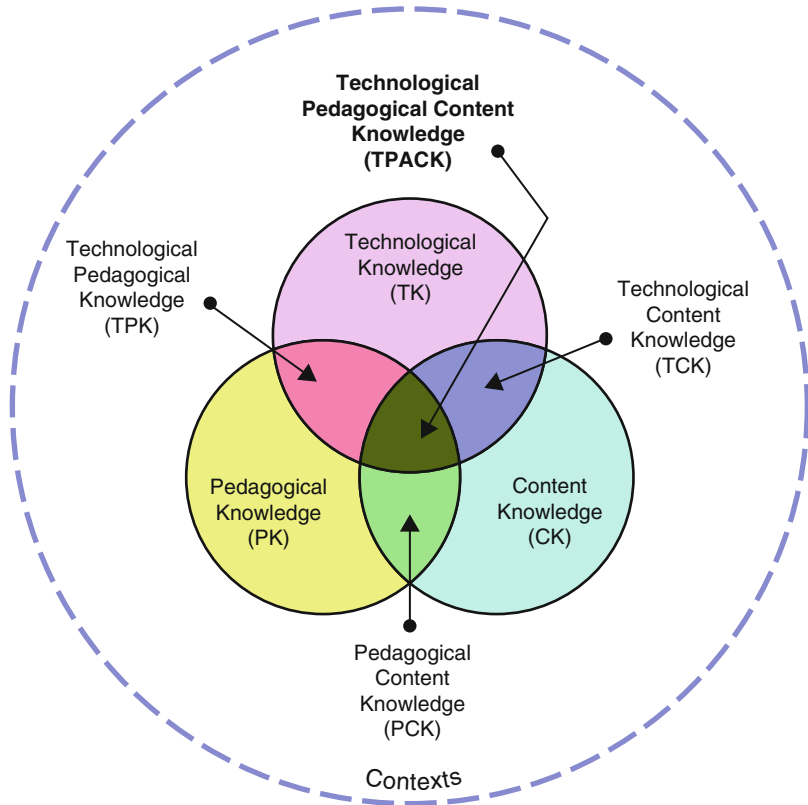
Student teachers also need to be made aware of the social and institutional contexts they could be presented with (Koehler and Mishra 2009) including barriers to ICT integration within schools. Cultural attitudes among teachers, the wider community including parents, and the general population can greatly impact upon the success of digital technology integration in schools. First-order barriers are usually classified as those extrinsic to teachers and involve, among other things, access to equipment, time, training, and support, while second-order barriers are intrinsic and related to the teacher's underlying beliefs about teaching, learning and technology, their established practices, and willingness to change (Ertmer 1999). More recently, third-order barriers have been proposed by Tsai and Chai (2012) which describe the struggle teachers have with “design thinking” (the ability to create what is desired) which could be used to help overcome first and second barriers. Design thinking skills allow teachers to creatively adapt their teaching style and content for the differing social and institutional contexts of schools they encounter, as well as the students and classroom dynamics. For example, computational thinking can be taught with offline activities if digital technologies are not available and creative use of technology allows for lessons that include ICT in ways that do not compromise pedagogical beliefs. Tsai and Chai (2012) remind us that because technology advances and changes at such a rapid rate, there will always be barriers to integration, making design thinking that much more important.

Including ICT in Teacher Education

While there is a general consensus that digital competence, sound pedagogical and content

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Fig. 2 The TPACK model
(Koehler and Mishra 2009,
p. 63)



knowledge, and well-developed design skills should be developed through teacher education, the way these aspects are included in teacher education varies widely. In a number of universities, ICT inclusion mirrors school curriculums, where some institutions have included digital technology as a separate unit, while others have integrated it across the teacher education curriculum. There have been numerous studies which focus on the effectiveness of initial teacher in adequately preparing future teachers to use ICT and to teach using ICT effectively. However the research indicates that initial teacher education is not adequately preparing future teachers (Wang et al. 2014; Sweeney and Drummond 2013). The reasons why are varied and complex, and there is no single idea or strategy that can be applied across contexts.

The Complexity of Preparing Student Teachers

In 2012, Tondeur, Van Braak, Sang, Voogt, Fisser, and Ottenbreit-Leftwich conducted a systematic

review of the qualitative literature to analyze the key ideas and strategies which underpin the methods found to be most effective in preparing student teachers for technology integration. The following framework was constructed using the findings, which indicated 12 themes for student teacher preparation. The framework has several levels and represents a micro to macro approach, from student teachers, to the delivery of units in initial teacher education, to the wider institutional considerations (Fig. 3).

Surrounding the intentions of teacher education to prepare student teachers to use technology are the methods of including ICT in teacher education programs, and the how, where, and when of ICT integration are described at a unit level. Important considerations at this level include:

- Role models: Ensuring that teacher educators are modelling the effective use of ICT to teach unit content, for example, using technology to effectively employ literacy pedagogy



Teacher Education, Thinking About ICT, Fig. 3 The synthesize qualitative data (SQD) model to prepare student teachers for technology use (Tondeur et al. 2012, p. 141)

- Reflection: Allowing student teachers time to reflect on ICT use and their beliefs and attitudes toward technology for education
 - Instructional design: Consideration of the planning and preparation needed when incorporating ICT into teaching and learning
 - Collaboration with peers: The positive experience of collaborating and problem-solving in groups
 - Authentic experiences: Playing with the technology in order to learn unit content rather than just watching
 - Feedback: The move from traditional assessment to continuous feedback
- Moving out further into the third circle, we can gain a sense of the institutional elements that are important, the ability of the teacher education institution and staff to competently employ these methods:
- Technology planning and leadership: The university strategy for effective education for student teachers about technology integration and their own levels of ICT competence
 - Cooperation between and within institutions: The ways in which staff support each other and universities liaise with schools and outside organizations to ensure consistent expectations

- Staff development: The ways in which teacher educators are educated about using ICT as part of their own practice
- Access to resources: The resources available for teacher educators and student teachers to use

The outer circle of Tondeur et al.'s (2012) SQD model described efforts to change teacher education institutions in systematic ways in terms of resourcing, attitudes, and delivery of education in recognition that student teachers responded most positively to ICT education when theory and time for hands on practice were aligned. Considerations for systemic institutional change include changes to course structure, including how, when, and how frequently technology is highlighted in teacher education programs.

Institutional Considerations

Most initial teacher education courses globally are mandated by governments and other bodies who ensure that initial teacher education has met any accreditation requirements. For example, Australia, Scotland, the USA, and the UK have professional standards for teachers that must be met by both graduating teachers and existing teachers within the field. In comparison, the UK and US professional teacher standards do not explicitly make mention of ICT within schools to support learning and teaching, although it is in the school curriculum and teachers would still use ICT within their practice. As an example, Australian Professional Standards for Teachers (Australian Institute for teaching and School Leadership 2014) mentions ICT integration and the requirements of being able to use ICT to support teaching and learning explicitly in three standards and has implications for the others:

Standard 1. Know students and how they learn.

Standard 2. Know the content and how to teach it.

2.6 Information and Communication Technology (ICT): Implement teaching strategies for using ICT to expand curriculum learning opportunities for students.

Standard 3. Plan for and implement effective teaching and learning.

3.4 Select and use resources: Demonstrate knowledge of a range of resources, including ICT, that engage students in their learning.

Standard 4. Create and maintain supportive and safe learning environments.

4.5 Use ICT safely, responsibly, and ethically: Demonstrate an understanding of the relevant issues and the strategies available to support the safe, responsible, and ethical use of ICT in learning and teaching.

Standard 5. Assess, provide feedback, and report on student learning.

Standard 6. Engage in professional learning.

Standard 7. Engage professionally with colleagues, parents/carers, and the community (Australian Institute for Teaching and School Leadership 2014).

Course Planning

While there is no consensus on the best way to include digital technologies in teacher education, there are a number of issues that need to be taken into account when deciding upon the structure. The first consideration is whether to include ICT education as stand-alone units, content embedded across all or a number of units, or a combination of both. At which stage of initial teacher education ICT will be emphasized is another consideration. This is particularly important when only one stand-alone unit has been allowed for in the course structure. Sophisticated pedagogical knowledge does not emerge until the later years of initial teacher education, so a first year student teacher with little exposure to curriculum content and pedagogical knowledge may not grasp the importance of aligning pedagogy with content or be unable to envisage a use for technology beyond the examples they have been given (McLeod and Carabott 2018). On the other hand, a single ICT unit introduced in the later years of teacher education may mean that student teacher digital competence and confidence are not as high as imagined or that they do not fully appreciate the importance of ICT in the school curriculum. As such, single stand-alone ICT units are usually deemed as insufficient for student teachers to be adequately prepared for the complexities involved in integrating ICT (Lawless and Pellegrino 2007).

Student teachers do not arrive at university with a standard level of digital competence, and it is not something that can be developed within one 12-week unit. Not only do student teachers need time to play with ICT to develop their technological knowledge, they also need to build their understanding of digital competence and increase their confidence across a period of time. Increased exposure to ICT, both theoretical and practical, within teacher education units and degrees increases competence and enhances pedagogical understandings.

Where ICT is embedded across the curriculum, teacher educator digital competence becomes a significant factor. Academics, mirroring complaints from in-service teachers, suggest the digital content of their units is constrained by their own competence, interest, lack of time, and the resources available where the course is taught (Black and Smith 2009). Where ICT was embedded across units, student teachers have suggested that not enough was done to help them understand how ICT could facilitate their own teaching (Lei 2009). In one case study, Black and Smith (2009) found 46% of student teachers said that their initial teacher education had no impact on their digital competence. In the same study, only a third of student teachers believed their lecturers modelled embedding ICT well. In addition, “the

ICTs modelled rarely got beyond PowerPoint, while ‘academic’ staff seemed openly afraid or disinterested” (Black and Smith 2009, p. 21).

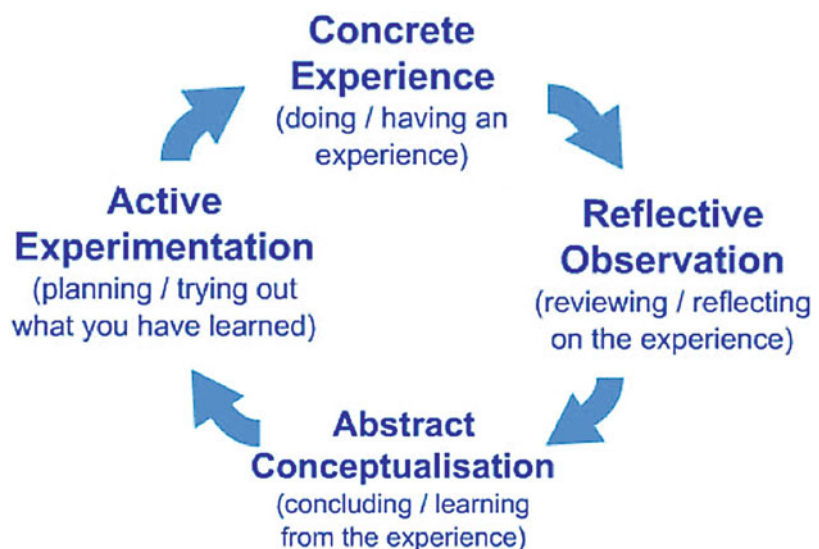
Unit-Level Approaches

The second circle of the SQD model (Tondeur et al. 2012) emphasizes the practical implications for teacher educators in relation to unit construction which should allow for role modelling, reflection, continuous feedback, collaboration, authentic experiences, and an appreciation of instructional design.

Traditional forms of university teaching involve the teacher educator standing up in front of the class and delivering the content in a didactic way, normally a lecture format. However, these didactic approaches may not be suitable for ICT development. This was evidenced by McLeod and Carabott (2018) who found that student teachers who only observed ICT being modelled were unable to imagine digital technologies as anything more than mere tokens used for motivation or engagement. This resulted in little change in the student teachers’ digital competence or understanding of its relationship with pedagogy or content knowledge.

Experiential learning is at the heart of teacher education as it is through both theory (units of study) and practice (professional practicum) that

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Fig. 4** Experiential
learning cycle. (Adapted
from Kolb (1984))



student teachers are educated. Kolb's experiential learning cycle involves forming abstract concepts, testing them in new situations, having a concrete experience, and observing and reflecting, which is then used to form further abstract concepts (Kolb 1984) (Fig. 4).

Experiential learning allows students to apply the knowledge or conceptual understanding gained to real-world problems. When the relevance of the experience is revealed, motivation, self-direction, and organization are increased allowing students to more effectively integrate new material with prior knowledge (Weinberg et al. 2011). Students are able to learn at their own pace or level, allowing differentiated learning (Beard and Wilson 2006) which is particularly important as student teachers arrive at university with varying levels of digital competence.

Some universities are employing experiential learning to help student teachers understand more about incorporating ICT in their lessons. McLeod and Carabott (2017) found that asking student teachers to create a digital object as part of a unit assessment task increased their understanding of the technological and pedagogical aspects of ICT in teaching in three main ways. Firstly, when creating with ICT was compulsory, as part of the assessment, student teachers increased their technological abilities with ICT – something they found challenging but rewarding. Secondly, student teachers were put in the position of learner which helped them understand problems their own students might face. Finally, and perhaps most importantly, student teachers recognized the opportunity to put theory into practice which gave them a deeper understanding of the unit content.

Student teachers participating in experiential learning have reported surprise at the level of thinking and engagement required in creating a digital object and that their attitudes toward using ICT in the classroom had changed as they realized the learning opportunities digital technologies allowed if used well (McLeod and Carabott 2018). When evaluating digital technologies using critical frameworks such as SAMR, the advantages and possibilities of digital technology

in education became easier for student teachers to imagine, and they gained a better understanding of why digital technologies are heralded as able to transform education. As well as deeper understanding of the technological and pedagogical aspects of ICT in the classroom, student teachers also showed a better understanding of how ICT was included in the curriculum and the expectations of teacher digital competence (McLeod and Carabott 2018). A greater intention to use digital technology for teaching and learning in their future classrooms was developed, and student teachers began to see beyond the superficial use of ICT, enabling them to engage in a deeper, experiential evaluation of technologies for learning.

Summary

It appears that ICT education is not being addressed adequately within initial teacher education as many student teachers are not reaching the levels of competence envisaged to deliver the curriculum (Lei 2009; Sánchez et al. 2011). Assumptions about the level of digital competence student teachers possess, no consensus on the best way to include ICT in course structure, and a lack of confidence among teacher educators as to how best ICT should be embedded at the unit level add to the confusion. In addition, while recognizing that sophisticated understanding of the interplay of ICT with pedagogical and content knowledge is required by student teachers in order to effectively enhance teaching, research on whether ICT benefits learning is still inconclusive.

In terms of content, ICT education covers a wide range of areas. In many school curriculums, teachers are required not only to teach ICT competence but to use ICT to enhance learning and teaching in other subject areas. To do this well, student teachers need to be exposed to tools that help them evaluate technology and its pedagogical worth when employed to teach subject content. Importantly, an ability to adapt ICT use to the sometimes less than ideal social and institutional contexts in which teachers find themselves needs

to be developed, along with an understanding and confidence that when faced with unknown digital technologies, an opportunity to model collaborative learning and risk taking is presented.

Initial teacher education institutions have a responsibility to ensure that course design reflects the standards set by government and professional teaching bodies. Based on an understanding that teacher education comprises both a theoretical and practical component, course design should include authentic, collaborative ICT experiences that allow the opportunity for feedback and reflection. Decisions need to be made about whether teacher educators should embed ICT for teaching and learning across a variety of units or whether one or more dedicated digital technology units should be included in course design, and the way in which the content is delivered – the balance of theory, role modelling and hands-on activities, optional or compulsory production of digital content, and the amount of time allowed for instructional design and reflection – all need to be considered.

Traditional didactic approaches, where ICT is role modelled to students without allowing them authentic experiences, could be replaced by participation in experiential learning, where time is made available for student teachers to experiment, reflect, and form new ideas, which leads to a deeper understanding of the potential of digital technologies in education. Student teachers who are required to put themselves in their learner's shoes and step outside their comfort zone to create, reflect, and problem-solve using digital technology begin to overcome the third-order barrier of lack of design thinking. The research suggests that when experiential learning using digital technology for assessment is used in addition to active embedding, student teachers are more likely to understand ICTE (and TPACK). A greater intention to use digital technology for teaching and learning in their future classrooms is developed, and student teachers began to see beyond the superficial use of ICT, enabling them to engage in a deeper, experiential evaluation of technologies for learning.

Cross-References

- ▶ [International Reports \(Including OECD\)](#)
- ▶ [Rationales for Information Technology in Schools, Historical Perspective](#)

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Teacher Knowledge Development

- [Restructuring Teachers’ Knowledge for Teaching with Technologies with Online Professional Development](#)

Teacher Trainees

- [Ethics and Learning for Teacher Trainees, Team-Based Simulations in Cases of Bullying in School](#)

Teacher–Student Communication

- [Teacher–Student Relationship and Online Social Networks](#)

Teacher–Student Interaction

- [Teacher–Student Relationship and Online Social Networks](#)

Teacher–Student Relationship and Online Social Networks

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Synonyms

[Teacher-student interaction](#); [Teacher-student communication](#)

Teacher–Student Relationship: Definition, Role, Importance

Relationships between teachers and students are complex, and are usually defined within the school setting. Hence, they are many times referred to in a context that entails class management. These relationships are evident in the interactions between teachers and students, and focus on the social and emotional aspects of the learning environment. The interaction is based on actions of one party (either the teacher or the student), followed by a reaction of the other party. Conceptualizing teacher–student relationships, Hamre and Pianta (2006) noted that in addition to individual features, three components shape the relationships between teachers and

students: perceptions and beliefs, information exchange processes, and external influence.

Studies regarding teacher–student relationships and student engagement show that positive relationships were associated with higher levels of engagement, achievements, school attendance, and positive behavior, and with lower levels of suspension and dropout (Quin 2017). This indicates the central role of relationship between students and their teachers, especially with the latter’s role shifting from “a sage on the stage” to “a guide on the side.” As a result, formal traditional educational paradigms are making way to more contemporary modes, focusing on connecting teachers and students within a mentoring relationship that empowers them and addresses their well-being and their self-fulfillment as future citizens. Teachers are expected to fully and truly understand their students’ needs in the information era, utilize alternative teaching approaches, and establish authentic relationship with their students that reflect compassion and caring (Rodgers and Raider-Roth 2006).

Student–teacher relationship is key to students’ academic, social, and emotional development, and may altogether affect the educational environment (Sabol and Pianta 2012). They may also promote students’ feelings of safety, security, and belongingness, and eventually lead to higher academic achievements (Pianta 2006). Positive or negative teacher–student relationship might also influence teachers’ well-being and professional development. Hence, positive teacher–student connections and relationship are of importance to all concerned.

Digital media opens new opportunities for communication between teachers and students as an integral part of their relationship, including instant messaging services (e.g., WhatsApp, Snapchat, Facebook Messenger) and social networking sites (e.g., Facebook, Twitter, Instagram). Due to their popularity among children and teens (Anderson and Jiang 2018), teachers and instructors often use these platforms as a way to “meet” with their students wherever they are (especially beyond school timetable). The use of these platforms is changing the communication de facto between teachers and students, and as a result, has the potential to transform teacher–student relationship altogether.

Online Social Networks as an Extension of the Physical World

Redefining Online Social Networks

The history of social networking sites (SNS) is as old as the history of the World Wide Web. Websites identifiable as SNSs have been launched since the mid-1990s. However, the emergence of the Web 2.0 and the social media in the early 2000s have facilitated the use of SNSs to a point when they became mainstream (Boyd and Ellison 2007). Some SNSs are used specifically for predefined goals – e.g., professionalism (LinkedIn™), photographing (Flickr™), scholarship (ResearchGate™), or education (Edmodo™) – while others have been formed for general use – e.g., Facebook™, Twitter™, or Tumblr™. For many years, SNS are among the most popular websites.

From their early days and until today, SNSs are aimed at bringing people together, allowing communication, and creating communities unbound by geographic and demographic restraints. As these activities have been always part of the human society, and as people have always been part of social networks in the physical world, we refer to these services as online social networks (OSNs).

Over the years, OSN have shifted their emphasis from being focused on the individual user to being focused on the interactions and communication between the users. Indeed, in the early OSN – like MySpace™, Facebook™, and LinkedIn™ – the personal profile was the pillar of the network; hence, users dedicated time and efforts to present themselves. Indeed, early definitions of OSN highlighted the *profile* (that is, the feature that allowed users to construct a personal virtual identity) as a major component of these platforms. The most common definition, still in use, is that of Boyd and Ellison (2007), according to which social network sites are defined by three characteristics – the construction of a personal profile, the creation of a list of connections to other users, and the ability to traverse the web of connections – all of which are profile-centered. This definition seems to be inspired by the fact that most users of OSN in the early days were teenagers and young adults, and within this population, self-presentation is of high importance.

This shift of focus – from being profile-centered to being communication-centered – is evident in the design and features of today’s popular OSN. Platforms like Instagram™, Google+™, Pinterest™, or Twitter™ offer a relatively limited profile and are designed to focus more on the communication between the network members. Furthermore, with the growing use of smart phones and other Internet-connected portable devices, and as many people today are almost constantly connected to the Internet, social networking is regularly maintained through platforms and services not previously identified as social networking sites. Specifically, mobile instant messaging services – like Facebook Messenger™, Snapchat™, or WhatsApp™ – have a great social impact on their users, and are now including features that resemble those of social networking sites (e.g., profile, list of connections).

As the boundaries between mobile instant messaging services and OSN (which are heavily used via mobile apps) are now blurred, we would refer to both as OSN and revisit the definition of this term. Hence, we propose to define online social networks as Internet-based platforms that allow their members (individuals, groups, or organizations) to interconnect; the dynamic web of connections formed by the network’s members lays the foundation for immediate, multimodal communication; members of these platforms distribute content within the network and across networks in various ways.

Blurring of Traditional Boundaries in the Era of Online Social Networks

The use of OSN for teacher–student communication is reciprocally associated with school boundaries. The frequent, free, immediate communication allowed by OSN is associated with the blurring of traditional boundaries between teachers and students. Communication via OSN entails functional and social advantages. These include information exchange and exposure to new information, facilitating a positive social atmosphere, creating a dialogue among students, and supporting learning – all of which are directly connected to teacher–student relationship. Therefore, the transformation in teacher–student

communication may, in turn, affect teacher–student relationship at large.

However, this type of communication is not without challenges and obstacles. Obviously, teachers and students can communicate effortlessly, as individual network-members, in OSN. Nevertheless, as these platforms are somehow an extension of the traditional social network in the physical world, this communication is inherently highly social; that is, it is often characterized by self-disclosure and exposure. Considering communication between teachers and students, this may lead to a collision between the very nature of the communication and the traditional hierarchical order according to which teachers and students are not equal. Therefore, the issue of teacher–student communication via OSNs should be examined comprehensively, from a broad perspective that highlights its impact on traditional teacher–student roles, hence the importance of exploring teacher–student relationship in the OSN-era.

Policy

Teaching in the information era has become more complex as SNSs are becoming more popular. Teachers are expected to be updated and relevant for their students by their superiors, to be professionals in a media- and communication-saturated world, but also to be connected to their students and exhibit caring and concern for their well-being. This explicit policy is accompanied by possible implicit consequences, to weaken and even shake the existing traditional hierarchic structure of schools and the centralization of the education system as a whole.

Consequently, policymakers and teachers feel the need to re-define their educational role, shifting its emphasis from a formal-traditional instructional paradigm to a mentoring paradigm, thereby addressing the need to relate to students and assist them in their educational journey. This is especially significant in the digital era, in which information is accessible and available online. The popularity of OSNs created a setting in which the communication between teachers and students and the relationship between them

is extended; hence, they are considered platforms for establishing additional and even alternative routes of communication. However, while OSNs enable growth and flourishing of these relationships, they pose some challenges for all parties involved. Along with the requirement from teachers to know their students and address their personal needs, they are required by policymakers worldwide to avoid a situation in which boundaries between teachers and students, as well as boundaries between school and beyond, are blurred. This paradox is rarely addressed in policy documents or instructions, and is generally avoided. In some cases, teacher–student relationship on OSNs are prohibited altogether, or restrained to educational purposes only; this in turn contradicts the need to address the students as an individual with feelings and needs beyond the formal academic ones.

Some of these contradictions are a result of the digital divide between teachers and students that creates inequality between teachers and students with regards to digital literacy. This is also an issue addressed by policymakers, which in general encourage teachers to develop their digital literacies. By this, the probability of misuse of OSNs is reduced; however, the principle itself of the extent and modes of communication and the nature of teacher–student relationship as an outcome of this communication remains.

Furthermore, policy does not take into account the diversity of OSNs, in terms of their nature, their structure, and their privacy options, to name a few characteristics. When required to address the use of OSNs, what typically occurs is that policymakers' decisions are dependent and based on the most popular OSN at the time. For example, when Facebook was popular, policy was usually based on this specific OSN and its unique features, e.g., the availability of groups versus pages, the public versus private options, etc.; this dependency on one widely used network in decision-making regarding the use of OSNs for teacher–student communication may have excluded some essential aspects, for example, the connection feature (befriending vs. following).

Development During the Former Decade and Current State

School authorities and policymakers have been contemplating their position regarding student–teacher SNS-based communication. Education systems worldwide have adopted different educational approaches, often prohibiting teacher–student communication via OSNs altogether, sometimes as a means to avoid dealing with the complexity of the matter.

According to updated Israeli regulations, teacher and students are allowed, even encouraged, to communicate on Facebook following rules that cannot be enforced, e.g., only via a closed group, opened by the teacher, and communication only by using a separate Facebook profile (colliding with Facebook regulations), lacking any personal information. This demonstrates policymakers' confusion regarding OSN in education at large. Worldwide, policies span from banning teacher–student communication via OSNs, due to concerns of blurring boundaries between professional and personal lives, or the need to protect students from sexual harassment. These policies expect teachers and students to use only school-provided platforms.

Public discussion focusing on teacher–student communication via OSNs reflects the multifaceted nature of the matter, demonstrating, on one hand, the difficulty in adapting novelties in large-scale systems and organizations, and, on the other hand, indicating the tendency to utilize OSNs, which are anyway used for communication, also in schooling context. However, in many cases, policies are based on public opinion, local culture, and the nature of educational systems rather than on empirical evidence.

Evidence from Research

Although researched extensively in higher-education contexts, research on the use of OSNs for teacher–student communication in primary and secondary schools is lacking and insufficient, and is mostly focused on pedagogy (Tang and Hew 2017). The few studies that focus on teacher–student relationship in the context of OSNs indicate on advantages of this

communication, which include functional and social aspects, e.g., information exchange, facilitation of a positive social atmosphere, creation of dialogue, and support of learning (Pennings et al. 2014).

OSNs allow an enmeshment of teachers' personal lives and professional arena. They also enable students to bring their personal lives into a formal educational context (Greenhow and Askari 2017). This sets the basis for communication opportunities between teachers and students, which broaden the interaction between them regarding school matters, as well as other topics of interest. Doing so, it also sets new relationships between teachers and students. The penetration of teachers into their students' lives and vice versa is challenging, technologically, but also socially, psychologically, and for teachers – professionally.

The opportunities and possibilities of communication between teachers and students using OSNs are quite comprehensive. The communication becomes convenient and immediate, allowing both parties to practice real-time interaction, unbound to time or space limitations (Claessens et al. 2017). Hence, in spite of policy limitations in many countries, states, and districts, communication is evident and based on needs of both parties. The teachers connected to their students via OSNs are aware of policy limitations, but still communicate with their students (Asterhan and Rosenberg 2015). The reason is that both teachers and students appreciate and acknowledge the contribution of OSN-based communication to their relationship, and also to their students' academic outcomes.

Since OSNs are in use by both populations anyway, it seems only natural that students prefer this channel of communication over other, more formal possibilities, as private or public space for their social interactions. This may lead to a situation in which some students and teachers would like to, and may in fact, extend their well-established relationship beyond school setting. Extending their communication to OSNs may promote, in return, their relationship within the school setting.

Apparently, teachers who want to communicate with their students via OSNs are younger, less

experienced in teaching, and more experienced with social media altogether. They are also more supportive of using OSNs for learning and disagree more with a banning policy of OSNs for teacher–student communication. As for students, those who would like to be connected with their teachers are older, and have a wide range of OSN connections. They also believe more than their younger peers in using OSNs for learning, and disagree more with a banning policy of teacher–student communication using OSNs.

Broadening communication facilitates a notion of closeness and trust between them. This may in turn create a sense of intimacy that allows students to be sincere and open with their teachers. Therefore, this communication may have an impact on students' well-being altogether. Additionally, this communication may develop the students' future communication skills. Indeed, students perceive several benefits of communicating with their teachers via OSNs. These include the availability of teachers, with digital platforms serving as mediators in instances in which face-to-face communication may be awkward for students. OSNs also allow separation between private and school-related topics by utilizing different communication channels.

OSNs present possibilities of greater accessibility of students to teachers and vice versa. This could be the reason that teachers are also generally interested in broadening communication with their students and in using OSNs for learning purposes, in addition to their usage for mere communication; the ramifications may include improvement of teaching itself, dependent on teachers' professional development and learning regarding best practices of OSNs, as well as practice related to digital media literacies – these allowing in turn new types of communication. Teachers perceive OSN-based communication with students as serving multiple purposes: broadening of teaching and learning possibilities, psychological support, and deepening of the relationship altogether.

This connection is favored to a larger extent by the teachers, who see OSNs as a convenient means of conveying practical messages, based on mutual needs. Hence, the benefits of

communicating via OSN (e.g., broadcasting, multimedia, notifications, etc.) facilitate their use. The number of teachers that report they would like to be connected to students is twice as much as those who are connected *de facto*, and the former tend to perceive teacher–student OSN-based communication in a more romanticized manner than manifested in practice (Forkosh-Baruch and Hershkovitz 2017).

Naturally, communication between teachers and students using OSNs raise some debate and even controversies. Even the very term used in many OSNs to describe users that are connected to each other – “friends” – may challenge traditional student–teacher hierarchy, since traditionally teachers’ role allows them some power over their students, even when close relationship between the two are developed. Issues of controversy may be related to issues of privacy and disclosure of information. It seems that conflictual experiences in real life are translated to Facebook communication, and vice versa. Hence, it is understandable that teachers prefer having a professional profile for communicating with students in order to separate between their professional and personal spaces. Also, both teachers and students handle communication that is considered personal using private communication channels, such as messengers.

Both teachers and students understand the negative aspects of communication using OSN, including issues such as: invasion of privacy, excessive information (these two being most prominent claims), undermining teacher authority and respect, exposure to inappropriate or offensive student behavior, blurring of boundaries, inequity in opportunities for communication, poor or insufficient ICT literacy, improper behavior of both parties, and addressing identity issues. Students perceive negative aspects, such as overload and excessive noise caused by lack of focus and ill decision-making regarding importance of issues within the communication. Altogether, both teachers and students face the need to cope with an educational paradigm shift, in which both populations cope with changes in their roles; this is especially difficult for teachers, whose traditional role is changing rapidly within a

technology-saturated setting. While students have deep understanding of social media – teachers’ media literacy is altogether challenging and requires acquisition of skills and competencies. This literacy is a prerequisite for adequate teacher–student communication using OSNs, if a teacher chooses to do so.

Despite the intriguing challenges, and despite regulators’ attempts to limit teacher–student OSN-based communication, teachers tend to disagree with a banning policy. Surprisingly, students tend to agree with such a policy.

Conclusions

When addressing the topic of OSNs in education, there is a need to refer to the role of both teachers and students. Since the schooling system is hierarchic in nature, while communication on OSNs is flat and equal in nature, there seems to be built-in tension in this channel of communication. The possibilities, as well as the pitfalls, of utilizing OSNs for communication between teachers and students are enormous; in both cases, consequences may be life-changing. Therefore, this should not be referred to lightly, but rather studied in depth and comprehensively.

The psychological aspect of flattening the communications between students and teachers in terms of hierarchy, but enriching the interaction by broadening the communication beyond the physical arena, to the virtual spheres, may be beneficial to both students and teachers. They may utilize these new possibilities and broaden their relationship with each other. The drawbacks may include, first and foremost, invasion of privacy. Extending teacher–student communication beyond the classroom may impact mostly teachers, who may experience excessive effort in terms of separating between their personal and professional online identities. This requires support for teachers who are willing to dive into this position. Hence, these teachers should be digitally literate, in order to wisely use the new possibilities that OSNs enable for communicating with their students. This is quite complicated for teachers, some born prior to the OSN-era. However,

students, who are typically more digitally literate compared to their teachers may also not be using OSNs wisely, unaware of the consequences of some of their actions. Therefore, while opening new possibilities, communication via OSNs also carries some impediments.

Implications

The implications for promoting teacher–student communication using OSNs are twofold, including aspects of teacher training and their professional development and aspects related to policy.

Implications for Teacher Training and Professional Development

Teacher training is key to their professional development in the field of digital media, since most teachers are unaware of both technological and social-ethical aspects of using OSNs. Hence, there is a need to encourage teachers to develop their ICT literacy, including skills and competencies, in order to use OSNs wisely. This may be achieved by formal on-the-job training as part of teachers' professional development, or by practical usage of OSNs and monitoring and support by mentors. These mentors can be digitally literate teachers; all teachers could bring their experience regarding controversial situations into these programs. This will allow teachers to make informed decisions: to achieve proficiency as SNS users, to utilize OSNs for better communicating and learning, and to handle ethical aspects wisely, e.g., privacy issues and data usage. This training process should begin in pre-service teacher training, before teachers enter the education system, so teachers may avoid the pitfalls of blurred boundaries. Finally, teachers should realize the differences between private and public channels of communications and wisely conduct their communication accordingly, in a way that best fits their educational agenda. This will allow teachers to further gain their students' respect and trust.

Implications for Policy

Policy can promote or hinder teacher–student relationship, since policymakers are those who

set the educational agenda, whether national or local. Therefore, policy must not be taken lightly, and decisions should be established after studying evidence-based research conclusions.

By setting up policies that limit teacher–student OSN-based communication, policymakers convey a notion according to which teachers are not to be trusted and should not be given an opportunity to act upon their educational beliefs. The new media-saturated era conveys an opportunity to implement a more liberal policy, enabling teachers to practice their profession based on personal beliefs regarding the nature of education and the nature of teacher–student relationship.

Policymakers should trust teachers with decision-making regarding their relationship with their students – just as they are trusted with teaching them. Hence, comprehensive banning of OSN-based communication is potentially damaging to the education system at large, and to teachers' and students' well-being. Furthermore, a policy of “one size fits all” goes against personalization of learning, which has always been the pillar of education; therefore, policy should reflect a pluralistic view of OSN implementation in education.

Cross-References

- [Social Media for Tertiary Education](#)
- [Social Networking in Higher Education](#)

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Teaching

- [Information and Communication Technologies in Chilean Schools, from Enlaces to the Present Day](#)
- [Pedagogical Possibilities for the History of Computing](#)

Teaching About Computing

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Synonyms

[Computer science education](#); [Computing education](#); [Didactics of informatics](#)

Introduction

My understanding of this encyclopedia is that it is likely to have a fairly broad audience including researchers, teachers, other educators, and anyone interested in computing education. So the entries need to try to capture the current thinking, including issues, challenges, controversies, what is known, and what is not known. They need to draw on the literature, but they are not systematic literature reviews or even full literature reviews rather they are written by experts drawing on their expertise and citing key references.

This entry “Teaching About Computing” describes the role of informatics systems in teaching about computing and is structured into two main sections: (1) [Application of Informatics Systems](#) and (2) [Comprehension of Informatics Systems](#). “Application of Informatics Systems” is the most underestimated part of teaching about computing. Therefore a discussion of the “[Cognitive Dimension of System Application](#)” as well as the “[Non-cognitive Dimension of System Application](#)” will be presented.

The entry teaching about computing should work as an overview and is therefore related with more specific entries of this encyclopedia, e.g., “► [Competency Models in Computing Education](#),” “► [Curricula in Computer Science](#),” “► [Value of Teaching Computer Science](#),” and “► [Computational Thinking](#).”

The learning environments should be designed to support application, comprehension, and

development of informatics systems. Our research studies have shown that there is an imbalanced number of lessons. This means that we spend much more learning time on development of informatics systems and too little on application and comprehension of such systems. The roots of this error lie in the underestimation of the necessary competencies for application and comprehension. The informaticians are not blameless on this problem, because they claimed for a long period that informatics systems would be easily and intuitively applicable in the near future. The worldwide community of users could observe the failure of this assumption. In contrary, informatics systems become more and more sophisticated, and small errors may lead to difficult circumstances in our real-life situations, e.g., strangers capture your computer for illegal business and you as an individual have to satisfy the cheated customers.

Therefore, we developed appropriate learning environments for application and comprehension of informatics systems, which delivered the evidence for successful learning of different kinds of cognitive models of informatics, e.g., von Neumann architecture, and models of layers (multilevel computer). After this experience, the next task was to establish a learning environment that could be easily integrated into a curriculum over the period of four half-year courses. The

international discourse with expert teachers culminated in the following structure: A, von Neumann architecture as course 11.2 (this means, the students are members of the 11th grade; students are approximately 17 years old); B, models of layers as course 12.1; and C, design patterns as course 12.2. After 12.2 the A-level examination takes place.

Application of Informatics Systems

According to their definition, competencies encompass both cognitive and non-cognitive skills and abilities. The application of the empirical method Critical Incident Technique and qualitative content analysis (Mayring 2003) established competence categories with respect to a scenario on application of informatics systems. A typical scenario is “Literature research with online catalogue versus search engine.” This scenario and its questions will be introduced to the interviewees as follows (see Fig. 1).

A further important scenario on system application is the following scenario: “You just installed the newest version of your favorite database system. There are lots of new functions hidden beneath an astonishingly changed graphical user interface.” This scenario has similar questions (see above).

Scenario: After reading a scientific article, you need more information in this area. To do so, you are using an online catalogue of a library and a web search engine. In case of the search engine, one query gives no results, a second one more than 3 million.

Question 1: What do you expect of such an online catalogue or a search engine?

Question 2: How do you get information with both systems?

Question 3: That cognitive skills are required for the application of both systems?

Question 3.1: That informatics views are important for this task?

Question 3.2: That complexity would you assign to this task?

Question 4: That attitudes or social-communicative and cooperative skills are necessary to accomplish this?

Question 5: That strategy would pupils apply to solve this problem?

Question 6: That obstacles would novices have to cope with?

Cognitive Dimension of System Application

All interviews were interpreted through qualitative content analysis. The first results of the qualitative content analysis have to be structured according to the dimensions of a competence model. Relations between the competence categories and meaning units in the interview have to be found and described (matching). For this we use the following expressions: answer plus competence category followed by the original statement of the expert (if necessary shortened).

As expected we found new subcategories for the competence category “System application.” With the following answers, the new subcategories are proved exemplarily:

- Answer “Use of media to foster system application and system comprehension”: “I expect there are a tutorial and a collection of good examples available. If the only resource to foster system application and system comprehension would be the manual (in general with thousands of pages) then we face a huge problem. Beginners will fail and other persons, that are more experienced, will waste a lot of time.”
- Answer “Structuring of application field”: “In general, all these themes are hierarchically structured. This means, we found the universal informatics concept hierarchical structuring in the application field.”
- Answer “Selection of systems”: “I choose the informatics system as a tool that offers the best relation between benefit and costs.”
- Answer “Transfer to new application fields”: “Abstraction is one of the fundamental ideas of informatics that is transferable to new application fields.”

For the competence subcategory “Selection of systems,” the experts stress for the comparison of the systems the need of appropriate selection criteria, and for “Structuring of application field,” they recommend two strategies, top-down design and stepwise refinement that are usually used together. The qualitative content analysis leads to “System control,” “Design of input

data,” “Evaluation of output data,” and “Selection of appropriate storage” for the competence subcategory “Paradigm of Information Processing (Extern).” The following answers are examples for these new sub subcategories:

- Answers “Design of input data”: “Key words have to be distinctive for one application field.” “You have to formulate precise queries.” “Complex queries have to be developed.”
- Answers “Interpretation and evaluation of output data”: “I need a vision of what I am looking for to evaluate the output documents.” “There is a difference between the results in an online catalogue of a library and the results given by a search engine. In the case of an online catalogue, a quality assurance process exists.”
- Answers “System control: extern”: All experts describe strategies to optimize the search process: “For the work with the online catalogue, you need experience with powerful key words.” “You should compare the traditional heuristic of a search with the web-based facilities to reduce the search space.” “In special cases you need also the strategy to extend the terms of the search.”
- Answer “System control: intern”: “If I want my web site to be listed as one of the first results with respect to a certain query, I have to use relevant key words as metadata of the web site.”

The following task could help the learners to develop the skills necessary to apply informatics systems (see Fig. 2).

The learners have to decide for each statement if it is true or false. We as teachers evaluate the decisions of the learners. If the decisions are correct, then the learner shows the following competencies:

1. The learner is able to recognize fundamental ideas and concepts of informatics.
2. The learner is able to abstract from the given example to the appropriate model behind the example.
3. The learner has the ability to analyze the unknown informatics system with the help of

Task: Your parents want to publish their best recipes in an online cookbook. They want to demonstrate the preparation of the food through videos. Your parents also have purchased a new software for editing the videos. Unfortunately, they do not know the software very well because they previously used an other program, which was especially designed for beginners. But they know that the new software uses the same Open-Source components to de- and encode videos as the old software. According to this, which of the following statements are true?.

Statement 1: Both of the programs own the option "Distort Video" that can be found under the menu point „Effects“.

Statement 2: Both of the programs can import audio files in different formats.

Statement 3: Both of the programs can import videos in the same format for editing.

Statement 4: Both of the programs can enhance the videos with effects.

Statement 5: Both of the programs support different view modes for windows.

Statement 6: Both of the programs can export videos in the same resolution.

Statement 7: Both of the programs are suitable for beginners.

Teaching About Computing, Fig. 2 Task on application of informatics systems

- such fundamental (mostly abstract) models of informatics.
4. The learner develops goal-driven and efficient strategies for the application of the given or selected informatics system.

Non-cognitive Dimension of System Application

In the competence dimension “Non-cognitive skills,” the qualitative content analysis lead to “Target orientation,” “Demystification,” and “Self-determined acting” for the competence subcategory “Expectations for informatics literacy and professional practice.” The following answers are examples for these new subcategories:

- Answer “Target orientation”: “I need a certain target orientation to formulate my query as precise as possible.”
- Answer “Demystification”: “Pupils need criteria to evaluate sources; otherwise they take the first matching result for truth.”
- Answer “Self-determined acting”: “If the first result is not helpful, you have to refine and modify your query again and again.” “We have to avoid being helpless in front of such system.”

Teaching About Computing, Table 1 Selected competencies of system application

Cognitive dimension	Non-cognitive dimension
(1) Use of media to foster system application	(1) Target orientation
(2) Structuring of application field	(2) Demystification
(3) Selection of systems	(3) Self-determined acting
(4) System exploration	(4) Cooperation and teamwork
(5) Transfer to new application fields	(5) Change of perspectives and roles (user, developer)
(6) Design of input data	(6) Openness to new ideas and new requirements
(7) Interpretation and evaluation of output data	(7) Learning motivation

But we found not only new non-cognitive sub subcategories. As expected any non-cognitive subcategories were proved (see Table 1). The following selected responses of interviewees are examples for these:

- Answer “Cooperation and teamwork”: “The plenary discussion would be the best opportunity to evaluate the draft design of a data model and to improve it stepwise in teamwork.”
- Answer “Change of perspectives and roles (user, developer)”: “Pupils have to play different roles with different rights (access to read,

Scenario: You are asked by a colleague to test his software, that was developed to solve configuration problems, e.g., to set up a new car or a new computer.

Question 1: What is your strategy of testing to solve this problem? That aspects do you have to bear in mind?

Question 2: That cognitive skills are required for such a software exploration?

Question 2.1: That informatics views are important for this task?

Question 2.2: That complexity would you assign to this task?

Question 3: That attitudes or social-communicative and cooperative skills are necessary to accomplish this?

Question 4: That differences of competence levels would you expect between novices and experts?

Question 5: How can you as a tester be supported by this task?

Question 6: Could you imagine a potential pupil's procedure to solve this problem?

Question 7: That obstacles would pupils have to cope with?

Teaching About Computing, Fig. 3 Scenario on testing of unknown software and its questions (Schubert and Stechert 2010)

access to write, access to delete) to learn more about the consequences of their decisions and actions.”

Answer “Openness to new ideas and new requirements”: “We have to provoke and to satisfy a huge curiosity for the exploration of informatics systems. On the other hand pupils need to have a high level of frustration tolerance.”

Answer “Learning motivation”: “We may use the attraction of similar applications like ‘Facebook’ on networked communities to stimulate the learning motivation of database application.” “Many pupils like to start a competition with a small problem solution that is incomplete, and the winner of the competition has to present the best improvement of the solution.”

This research phase has shown that the cognitive and non-cognitive dimensions of system application are mostly underestimated. We found very important subcategories, i.e., for the cognitive dimensions (Use of media to foster system application, Structuring of application field, Selection of systems, Transfer to new application fields) and the non-cognitive dimension (Target orientation, Demystification, Self-determined acting).

Comprehension of Informatics Systems

The application of the empirical method Critical Incident Technique and qualitative content analysis established competence categories with respect to a scenario on system comprehension. In Fig. 3 such an interview scenario is presented:

Table 2 shows the cognitive competence categories and non-cognitive skills that were mentioned by the experts with respect to system comprehension.

Change of Views

The competence dimension “Change of views” is very important. For problem-solving, the selection of the most appropriate informatics strategy is crucial for success. Therefore, theoretical foundations and practical tools have to be considered. Denning defines different views on informatics, i.e., “The five windows of computing mechanics” (Denning, 2003, p. 17). Therefore, a change of views is recommended between different solution strategies of problem-solving. Several experts mentioned that informatics is more than programming and should not be reduced to it. So, we have to offer more than the programming

Teaching About Computing, Table 2 Selected competencies of system comprehension

Cognitive dimension	Non-cognitive dimension
(1) System exploration	(1) Attitudes, e.g., expectations for informatics literacy and professional practice
(2) External view, e.g., observation of systems' behavior	(2) Social-communicative skills, e.g., change of perspectives and roles (user, developer)
(3) Internal view, e.g., paradigm of information processing	(3) Motivational and volitional skills
(4) Change of views	
(5) Scalability	

perspective. Moreover, the experts' statements lead us to the assumption that this competence dimension is incomplete if only a static sequence of "External view" and "Internal view" with their facets is considered. Thus, we insert a new category, "Change of views." Also the competence category "External view" needs refinement, but only with one new subcategory, "Paradigm of information processing (extern)," including input-output relations and state diagrams to explain and visualize the system's behavior.

Strongly connected to the selection of the most appropriate problem-solving strategy and, therefore, with the newly introduced competence category "Change of views" is the problem of scalability. It characterizes the phenomenon that an informatics strategy can be optimal to solve a given problem within a small informatics system, but the same strategy can be unrewarding given the same problem in a larger context. For example, in the field of informatics, we distinguish between "programming-in-the-small" and "programming-in-the-large." Thus, the scalability of problem-solving strategies is related to the complexity of a problem or an informatics system. The criterion scalability can be used to decide that solution (system, algorithm, process) should be applied to different problem sets. There are nearly no publications for the influence of scalability on system comprehension. Furthermore, scalability is an

evaluation criterion for the range of application of a given informatics system or tool. The experts' statements lead us to the conclusion that it is necessary to put scalability into the competence model as new competence category "Scalability," with strong connection to the other complexity factors.

Exploration of Informatics Systems

The following scenario "Usability engineering" belongs to the set of scenarios that should deliver research results on system comprehension: "You get software for the management of personal collections, e.g., books or DVDs. The software should be used on mobile phones. It is in your responsibility to test the usability." This scenario has questions similar to the scenario in Fig. 3. Here we found "System exploration" as an important new subcategory for the competence model. The experts answered: "When I want to choose free software, then I download and explore it."

Firstly, we insert this new competence facet into "System comprehension," but for a newly proved competence category or competence subcategory, there is more than one opportunity to add it to the competence model. All competence facets that are helpful for system application bring advantages for system comprehension, and the facets from there support system development in turn. So, we face the problem of deciding where the best place for each competence category and subcategory is in our model. In case of different possibilities, we recommend to insert it in each competence area. As an example "System exploration" could have been assigned to "System application" or "System comprehension." The majority of experts' statements in the scenarios indicate an assignment to "System application" and emphasize how important system exploration is in this competence area:

- Answer: "In this case, we have to use software exploration."
- Answer: "Pupils should work playfully with a database system to change from external to internal views."

The conclusion of these experts' statements is to introduce the new item as "System exploration" to "System application."

Summarizing, "System exploration," "Change of view," and "Scalability" are the most important results of empirical evaluation on competencies of system comprehension, because we have shown a close relation between application and informatics system comprehension.

The following task could help the learners to develop the skills necessary to comprehend informatics systems (see Fig. 4).

In Part A the learners have to allot the 1–3 errors to one of the stated meanings. We as teachers evaluate the decisions of the learners.

If the decisions are correct, then the learner shows the following competencies:

- 1. The learner is able to identify the errors produced by the informatics system.
- 2. The learner is able to distinguish between these errors.
- 3. The learner is able to evaluate such errors correctly.
- 4. The learner improves his tests of informatics system and avoids the same errors.

In Part B the learners have to decide for each statement if it is true or false. We as teachers evaluate the decisions of the learners. If the

Task: During his free time a friend of you has developed software, which can be used to calculate the volume of a cube. Thereby the volume of the cube is defined through the side length of the cube. Your friend asked you to systematically test the software. During the input of the side length it could happen, that you encounter the following errors:

- 1. Error: incompatible types - found "double" but expected "int"
- 2. Error: cannot find symbol - variable "quantity"
- 3. Error: stack overflow at line 201

Part A: What do the errors stand for? Allot the 1 -3 errors to one of the stated meanings. Each number only appears once.

No.	Statement
	You entered a decimal number instead of an integral number.
	You entered a string instead of the side number.
	You entered a symbol instead of a variable.
	The source code "stackoverflow" in line 201 is syntactically not correct.
	The number was accidentally entered twice (double) instead of once.
	The data volumes become too big for the reserved memory, because of an error in the program.
	The symbol for the variable "quantity" was not inserted in the source code.
	The variable "quantity" was not declared.
	You entered an integral number instead of a decimal number.

Part B: The values 0, 3, 5 and -3.5 have been tested. The program does not show any errors. Now, you enter the value 3000053. Which error tests this value, which has not been tested before?

- 1. The value tests if the combinations of the tested values lead to an error-free program start.
- 2. The value tests if integer values lead to an error-free program start.
- 3. The value tests if there are other incorrect parts of the program, which are used with big values.

Teaching About Computing, Fig. 4 Task on comprehension of informatics systems

decisions are correct, then the learner shows the following competencies:

1. The learner is able to apply well-known strategies of tests.
2. The learner is able to explain the advantages and disadvantages of different strategies of tests.

Conclusion

Application and comprehension of informatics systems are essential in teaching about computing. We could support teachers by their work in creating competency-based tasks for their students. Such tasks need to be connected to an empirically refined competence model. The examples of expert interviews given in this entry are only the beginning of a comprehensive research field. We face the issue to establish competence models for all parts in teaching about computing.

Although the deployment of the qualitative content analysis took place adhering to comprehensible, methodical rules and principles, it is inevitable that qualitative analyses are interpretative processes which might restrict the objectivity, reliability, and validity of the described analyses. We recommend the application of the following research methodology (Margaritis et al. 2015):

- The evaluation of the content validity of the model that can be accomplished by an expert rating. To make sure that we are not missing some important items by the used scenarios, we have to combine the interviews with a representativeness rating through the experts. This means, the different informatics experts have to rate the extracted competence descriptions concerning their relevance, difficulty, representativeness, and degree of differentiation.
- After this rating, we can develop instruments to measure (e.g., test items for the learning results, observation of learner-centered approaches) the different categories of the competence model in classroom practice.

- Based on the results of the measurement, we can focus on improving learning environments in informatics secondary education.

As described our project had the following intentions. First, we wanted to investigate which competencies are required to learn computer science in schools. Second, we aimed to design an instrument to measure some of these competencies. Third, this instrument had to be validated. Regarding these goals, we were quite successful. We found a convincing category system that provided a suitable structure for a competency structure model, which was applied successfully to other learning contexts already (Neugebauer et al. 2015).

Cross-References

- [Competency Models in Computing Education](#)
- [Computational Thinking](#)
- [Computers in Secondary Schools](#)
- [Curricula in Computer Science](#)
- [Value of Teaching Computer Science](#)

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Teaching Analytics

► Educational Assessment, Educational Data Mining, and Learning Analytics

Teaching and Learning Computational Thinking and Coding Skills

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Introduction

Digitalization is one of the most promising ways to increase productivity in society. In addition, it is widely accepted that digitalization will renew the economy, also substantially affecting the transformation of work life by creating new jobs resulting from innovation (Brynjolfsson and McAfee 2011; Mokyr et al. 2015). The educational system is also influenced by digitalization in at least two ways. First, the educational system is a platform that has been digitalized similar to the other sectors of society, meaning new learning methods, tools, and communication between schools and homes. Second, a digitalized education system is intended to build digitally literate citizens who have gained the skills to be active members of the digital society, participants in its economic, as well as in other societal, processes. Digitalization has influenced almost all work tasks and has created completely new jobs requiring competence to utilize computers and other digital devices (Frey and Osborne 2013; Niemi et al. 2014; Michaels et al. 2014; Bessen 2015). The implementation of digital services requires problem solving, design skills, logical thinking, understanding of how computers and networks operate, and programming competence. These abilities are useful for learning computer programming and computational thinking. This skill set can also be

considered coding skills. The term coding skills has various definitions ranging from narrow computer programming abilities to a general idea of computational thinking, a competence of formulating a problem and expressing its solutions in a way that an operator can effectively carry them out (Tuomi et al. 2017).

According to Denning (2009), computational thinking can be defined as the ability to interpret the world as algorithmically controlled conversions of inputs to outputs. In other words, computational thinking involves learning to think about, represent, and solve problems that require a combination of human cognitive power and computing capacity (Kafai and Burke 2013).

Computational thinking and coding skills are required to understand how our society and services work, and they will be increasingly required in future job descriptions. They can be seen as a set of skills every citizen should master. The Internet industry and the Internet of Things will expand the number of connected devices; in addition, different sensor-based solutions will produce large user, device, and environmental datasets. For analyzing these data, logical thinking, problem-solving, and coding skills are required.

Digital competence is fast becoming the most desirable asset in today's labor market, and 90% of all European jobs require computer skills at least on some level. Despite this, there is a growing gap between the number of European ICT vacancies and the number of skilled workers available to fill them. According to Balanskat and Engelhardt (2015), by 2020, Europe may experience a shortage of more than 800,000 professionals skilled in computing and informatics.

Computer programming has been taught at universities since the 1960s. However, only recently have educational systems started to understand the meaning of coding skills and computational thinking in general. The current job descriptions that include coding skills are for artists, developers, and producers. It is widely believed that learning coding skills leads to a more creative society. People are consuming more software and media products than ever, but only a tiny percentage of the population can

modify, customize, or create their own digital media and products.

The majority does not recognize the patterns behind digital products, which is the main reason that coding skills should be taught at every school. According to Microsoft, two-thirds of ICT jobs exist in non-ICT industries (from the manufacturing and automotive sectors to healthcare and retail), and the transferable, creative skills learned through coding are applicable across a range of professions. In Europe's schools, computer science is more often seen as marginal, instead of being considered a foundational subject, like languages, mathematics, or science. Fewer than 15% of European students have access in school to the kind of high-level ICT teaching they need to develop collaboration, self-regulation, and critical thinking.

Numerous studies have pinpointed that students experience many difficulties in learning to program (Webber and Possamai 2009; Koscianski and Bini 2009; Lahtinen et al. 2005). Educators agree, however, that students need to learn a programming way of thinking, which is more than just knowing the syntax and semantics of a language (Holvikivi 2010). The most important distinction to emphasize is the difference between teaching programming as a subject and understanding coding skills as part of a general set of twenty-first-century skills.

Learning Theories for Computational Thinking and Coding Skills

No single learning theory describes how coding skills and computational thinking should be learned. In this chapter, two theories that have been shown to be useful are presented.

To extract young people's full potential, they need to understand how new technologies work. From the theoretical point of view, inquiry learning (IL) can be used to describe the learning process where students learn through internal curiosity and doing (Sharples et al. 2013). Panjwani (2015) stated that inquiry-based science education (IBSE) can increase pupils' interest in science while also motivating teachers (Panjwani

2015). According to various reports and studies, school science teaching must be more engaging through applying inquiry-based and problem-solving methods to meet the interests of young people. Inquiry-based learning is a method, which enables learners to discover different kinds of subject matter knowledge through inquiry experience. It starts by posing questions, problems, or scenarios – rather than simply presenting established facts or portraying a smooth path to knowledge. In this way, inquiry learning imitates how a scientist works.

Another theory describing learning in technological environments is Kolb's experiential learning theory (ELT). In ELT, learning is described as a circle, where concrete experience, reflective observation, abstract conceptualization, and active experimentation are phases of learning that follow each other. Through the process of moving from concrete experience to active experimentation, the learner experiences an event (such as the first iteration of programming code), reflects on the results (the program produces a certain output with a certain input), creates an abstract concept, designs a new version of the learning activity, and starts a new cycle by doing another experiment (such as running the program code again). The cycle can be repeated as many times as necessary. Kolb's theory supports students in applying their knowledge and conceptual understanding to real-world problems.

Inquiry learning and experiential learning theory aim to teach students the competencies they need for real-world success. The two theories support the idea of seeing the school and its surroundings as a holistic network of learning environments, focusing on children who today are learning the twenty-first-century skills they need to be successful in work and play in 2030 (Korhonen et al. 2014).

Coding Skills as a Part of Maker Culture

Coding skills are often related to the idea of maker culture activity. Maker culture is a contemporary culture or subculture representing a technology-based extension of DIY culture. Typical interests

include engineering-oriented activity (such as electronics, robotics, 3D printing, and the use of computer numerical control (CNC) tools), as well as traditional activities (such as metalworking, woodworking, and traditional arts and crafts). In maker culture, there is a strong focus on using and learning practical skills and applying them to create something personal. Simple examples of maker culture include the trend of customizing your mobile device (by adding stickers or small shiny stones on the phone cover) or customizing your clothes.

Maker culture focuses on using and learning practical skills and then applying them creatively to different situations. Maker culture draws upon a more participatory approach than traditional learning, encouraging learners to collaboratively engage with others as they learn through the creation of new items (Sharples et al. 2013). Maker culture then emphasizes informal, networked, peer-led, and shared learning motivated by fun and self-fulfillment (Niemeyer and Gerber 2015).

Three Approaches for Learning Coding Skills

As a part of twenty-first-century skills, future schools should teach the wide variety of coding skills in the best and most effective ways. In a previous study, different approaches and methods of promoting coding skills in formal and informal settings (i.e., in school and outside school environments) were classified. The three larger approaches for learning computational thinking and coding skills take place in:

1. Formal settings (schools within the curriculum)
2. Nonformal settings (online and after-school clubs)
3. Informal events (hackathons, jams, etc.; Tuomi et al. 2017).

In formal settings, the ways coding skills are approached in schools within the curriculum vary greatly across countries and cultures. In non-formal settings, different coding skill activities

take place in after-school clubs. In these club activities, children can achieve hands-on experience in coding and creativity for example, through creating devices using cheap computing hardware, such as the Raspberry Pi. A common theme of after-school clubs in relation to learning coding skills is robotics. Many studies indicate that educational robot activities have a positive impact on the development of students' critical thinking, problem-solving, and metacognitive skills (Atmatzidou and Demetriadis 2014, 2016) and on the learning of a programming language (Alimisis 2009; Nourbakhsh et al. 2005). Other studies demonstrate that educational robot activities promote an enjoyable mode of learning, in addition to advancing students' motivation, collaboration, self-confidence, and creativity (Miller et al. 2008; Eguchi 2010; Khanlari 2013). Diverse informal coding events (hackathons, jams, etc.) are taking place. Usually, they can easily be combined with school activities, but they are also accessible for individuals, outside school participation. Many coding events take place throughout Europe, such as the Hour of Code, the European Union (EU) Code Week, and the Year of Code. In many cases, schools utilize coding events and materials created by nonprofit organizations, governments, or companies. Coding skills are promoted through companies as a part of their business or corporate social responsibility programs, through organizations such as science centers, through charities, and through different themes, such as gender, robotics, and hackerfests. There are also several options to learn coding worldwide through virtual academies, such as the Microsoft Virtual Academy or Codecademy, at the individual level.

In the last few years, the diversity of job descriptions has also supported women to find the industry a more welcoming place to work. Despite this development, there are still few female programmers, coders, developers, and programming coordinators (Ensmenger 2012; Ilomäki 2011). Ensmenger (2012) studied the process of how and why the field has become predominantly male. The profound effect of the stereotypes embedded in advertisements and hiring practices on masculinizing this profession can

also shed light on what can be done to reverse the trend, making programming and other computer professions more open to women (Ensmenger 2012; Abbate 2012).

It is important, however, to be reminded about women's forgotten contributions to the computing field. According to Fritz (1996), the very first programmers were the women, for example, operated the Electronic Numerical Integrator and Computer (ENIAC; the world's first electronic computer) in the United States of America (USA) in the 1940s. In addition, the Bletchley Park codebreaking operation during World War II relied heavily on women. The recent lack of women in tech has been widely acknowledged (Ensmenger 2012; Ashcraft et al. 2012). However, since the situation has become more visible, it has started a movement to encourage women to engage with technology through different events and tech-oriented societies. Today, there are more resources than ever to help women break into the technology industry (Tuomi et al. 2017).

Coding Skills in Finnish Curricula

Teaching of ICT was introduced to the Finnish curriculum in the 1980s, starting first in high schools in 1982. Computer skills were seen as important, but the number of computers in Finnish schools was not adequate to reach all students. However, many computer activities were carried out in different computer clubs after school. Computer club activity was especially important in experimental schools in the early 1980s, although some computer courses had been available at a limited level in the late 1960s and 1970s (Saarikoski 2011). The teaching of computer skills in schools was clearly linked to the rise of the Finnish home computer market in 1983 and 1984. Computer hobbyists played a major part in the domestication of ICT skills. User groups, clubs, and subcultures emerged rapidly all over the country during the 1980s. The media image of home computers was also very positive, almost overly optimistic, at the time (Saarikoski and Reunanen 2014). During the 1980s, official reports and curriculum projects clearly

emphasized that youngsters should learn the basics of this new literacy. Predominantly, this meant that schools were obligated to purchase computers and other hardware. Computer training was also arranged for teachers. Computer education faced a lot of practical problems; for example, software support was weak, and teacher training was hastily arranged. In secondary schools, the actual subject of ICT was added to the curriculum in 1987 and 1988, when it became one of the optional subjects. In 1994, ICT started to lose its place as an individual subject. ICT skills became seen as a larger part of other subjects, meaning ICT could be approached through several subjects, and thus, it became more cross-curricula (Sinko and Lehtinen 1999; Vahtivuori-Hänninen and Kynäslähti 2012).

From the maker culture point of view, making things with your own hands has always been embraced in Finnish schools. Crafts as a subject in schools and in the curriculum have existed for decades. However, changes in society and in the labor market have affected the use of materials and techniques in the teaching of crafts (Kansanen 2004; Pöllänen 2009). In the 1970s and 1980s, crafts subjects included textile and technical approaches. Especially for boys, the subject of electronics paved the way for different handcraft activities based on the first computers that arrived in schools. Students tinkered with the actual hardware from scratch to make it work (Tuomi et al. 2017). The tinkering and assembling of hardware represented similar handcraft ideology that can be seen today in robotics, 3D printing, and such. Maker culture and crafts as a school subject was and is a familiar phenomenon in Finnish schools. It seems the schools are now experiencing the second wave that as before, acknowledges that coding or programming is much more than just typing the code, and can include operations that require a hands-on approach (Tuomi et al. 2017).

The new national core curriculum for primary education in Finland (from 2016 onward) states that programming, or coding, will be part of all education. In Finland, most lessons in grades 1–6 are taught by each class's own teacher; thus, classroom teachers must be able to understand and meaningfully use coding as a teaching and

learning tool. The curriculum states, for example, that to get a good grade in mathematics, a sixth-grade student must be able to create simple programs using a visual programming environment such as Scratch (although others are available; Tuomi et al. 2017).

Several coding-based workshops and events have also been developed in Finland that offer individual training possibilities, outside school activities (clubs), and teacher training. Currently, teachers in Finland are implementing the new national core curricula and are looking for the best practices for teaching coding skills at all levels of primary education. There is an actual need for ongoing support, and teachers and the teacher union have requested more training in coding skills for in-service teachers. The change in the core curricula has also activated educational publishers to produce teaching and learning materials for coding skills (Tuomi et al. 2017). The new national core curriculum crystallizes the vision of education for the future and the expertise needed in Finnish society. The ongoing curriculum process is a key factor in developing the educational sector in Finland for twenty-first-century skills and competences (Niemi et al. 2014).

Case: Learning Coding Through Play

Computer programming or coding has been included in the Finnish National Core Curricula (FNCC) since 2016. It is not an independent subject, but it is integrated in other subjects. The FNCC defines several transversal skills that should be taught and learned in every subject. ICT competence is among these transversal competencies. The FNCC states: “The teaching and learning make use of the information and communication technology (ICT) skills the pupils have acquired during pre-primary education and outside of school. Play-based working methods are still important.”

The FNCC states that pupils should work with digital media and age-appropriate programming tasks. Key content areas related to the objectives of mathematics in grades 1 and 2 state that “the

pupils began familiarizing themselves with the basics of programming by formulating and testing step-by-step instructions.” This also supports the development of logical thinking and problem solving. An example of a classroom activity suitable for learning step-by-step instructions is an activity where pupils work in pairs (pupils A and B). Pupil A acts as the computer and pupil B as the computer program. The aim is to give specific instructions to pupil A so that he or she can perform a simple task just by following pupil B’s instructions. A simple case is moving an object (e.g., a pencil) on a table from one point to another point, for example, from the left side of the table to the right side. First, the teacher explains the aim of the classroom activity and then divides the pupils into pairs. The pupils decide their roles as the computer or the computer program. Pupil A, the computer, must have a pencil on her left side on the table. The computer program (pupil B) gives instructions, for example: “move your left hand over the pencil,” “grab the pencil with your left hand,” “move your left hand up,” “move your left hand to the right about 10 cm,” “move your left hand on the table,” and “release the pencil from your left hand.” First, the pupils learn that the instructions should be precise and descriptive. In addition, the instructions should be given in the right order. If a step is misunderstood or is missing, the task will fail. In the next phase, the activity could be modified so that the computer program does not see what the computer is doing. This makes it necessary for the computer program to plan the instructions beforehand, and it is not possible to correct the instructions in the middle of the task.

The pupils and the teacher could discuss the concepts or words the computer program uses as an instruction. For example, is it assumed that the computer understands every word the computer program says? The final phase could be that the pupils design a list of the instructions the computer understands and then try to do the task using the limited instruction set. In addition, the pupils could plan the task by themselves. It does not have to be the moving the pencil task, but it could be, for example, a drawing task. In this case, the computer has a piece of paper and a pencil, and

the task is to give orders to draw, for example, a house.

Games can also be used in learning computer programming. Several games specifically teach logical thinking, and some games teach programming as such. For example, a game called Foos is available for iOS and Android devices (www.thefoos.com). In the game, the player solves a set of puzzles in a world called Foosville. The game uses an icon-based graphical programming “language” that is used in solving the puzzles. The Foos web pages have materials for teachers so that they can develop their own lesson plans for the Foos game. Another game that teaches logical problem-solving is called Wuzzit Trouble, designed by Dr. Keith Devlin from Stanford University. Similar to the Foos game, Wuzzit Trouble has no written words, so it can be used in various countries and without any knowledge of English (or any other language). In the game, the player tries to open a lock in a cage and release a cute Wuzzit character from the cage. The lock can be opened by operating the gears, which the player can turn. Opening the lock requires a certain set of operations with the gears, so logical thinking is needed.

Case: Learning Coding with Visual Programming

In the FNCC, the aim for grades 3–6 is to try out computer programming in a graphics programming environment. The key content areas that computer programming contributes are related to the mathematics subject and to thinking skills and data processing skills.

Graphical programming environments are an easy way to start to learn programming. Several applications and web sites implement a graphical programming environment suitable for learning programming at school. One of the popular environments is Scratch, a free programming environment that can be used with a web browser. In Scratch, there is a stage on which the pupil can put graphical objects. Each object can have its own short program. The programs are presented as flowcharts, and the pupil can drag and drop

flowchart icons to the program. The icons are like puzzle pieces snapping together when they are in the correct place. The flowchart icons have text labels, so the pupil needs to understand written language.

Programming in a graphical environment is generally very easy. For example, the main character in Scratch is a cat, which can be programmed to move around the stage. The pupil can also easily add sounds. The first programming tasks in the Scratch environment could be to create digital animations and stories. In addition to programming, pupils can design their own objects to be put on the stage. Working in the Scratch environment integrates other subjects well, as designing objects could be art class work and creating the storyline could be something that is typically done in drama class.

Pupils can share their work in the Scratch environment with other users. This is also an important way to learn coding. Looking at how others have implemented something is actually a common way to learn programming in other programming languages. Many professional coders share their questions on Internet discussion sites (such as Stackoverflow) and get help from other professionals.

Although Scratch is an easy environment, it is quite powerful. For example, many great interesting games are implemented in Scratch.

In addition, the ScratchJr version of Scratch is available as an iPad or Android tablet app. ScratchJr is designed for younger pupils (preschool), and it does not require any reading skills. The flowchart icons do not have any text. In ScratchJr, pupils can also create stories and animations.

In graphical programming environments, pupils learn many core programming concepts. Variables, instructions, loops, *if-then* statements, functions, and objects are all present in graphical programming environments.

Case: Learning Coding with Robotics

A well-known robotics environment for kids is Lego Mindstorms EV3. It integrates Lego blocks,

sensors, and motors in a graphical programming environment where pupils can create moving robots that can do different tasks. In Finland, robotics has been an after-school activity for several years, but the FNCC 2014 brought robotics into school.

Lego Mindstorms EV3 includes making a robot using the available blocks and components. There are also simple robots that can be programmed without making the robot first. SPRK is a robot shaped like a ball, and it can be programmed with a graphical programming language by using a smartphone app. The smartphone is connected to the robot by a Bluetooth connection. The ball can be programmed to travel through a certain route, and the ball can detect its orientation, position, and collision to another object. In a classroom, the teacher can use these robots, for example, to create a competition for whose robot and program travels a certain route the fastest. The pupils would then create programs for the robot and then let the robots compete against each other.

In Finland, computer programming also integrates crafts in grades 3–6. In general, the key content areas in crafts include producing ideas, design, experimentation, production, application, documentation, and assessment. In the crafts subject, pupils experiment and design with a diverse range of materials, such as wood, metals, plastics, fabrics, and recycled materials. In addition, “they practise with functions produced the help of programming, such as robotics and automation” (Finnish National Board of Education 2016, Ch. 14.4.12).

Discussion

The Microsoft news center emphasizes that digital skills are life skills. However, the lack of programming and computer science in K–12 education is increasingly recognized as a serious lack in the national curricula of many countries (Guerra et al. 2012; Sengupta et al. 2013). According to Dagiene et al. (2014), many European countries have included informatics in their curricula since the 1970s, but many of these efforts have been dropped for various reasons. Therefore, many

students graduate from secondary school with quite a lot of experience of using computers and software, but little, if any, knowledge of the underlying principles (Dagiene et al. 2014).

The European Union has started to support the introduction of coding in schools. Learning to code teaches essential abilities, such as computational and abstract thinking, and it is just one of a wide range of digital competencies that could help Europe’s children enhance their creativity, flexibility, and problem-solving skills.

Teaching coding skills does not happen without the teacher. It is important that teachers are educated, guided, and supported at the practical level to meet the requirements of coding skills in the curriculum. Many countries are including twenty-first-century skills, computational thinking, and coding skills in the curriculum, but many countries lack, at the national level, official and adequate education and training for teachers for implementing coding-based activity in their school work. Gathering the different practices worldwide would promote the idea of lifelong learning and support the modernization of education and training systems, in particular through recognition and the dissemination of good practices. Maker culture has the potential to contribute to a more participatory approach and create new ways to learn technology-related topics. In addition, maker activities support learning Science, Technology, Engineering, and Mathematics (STEM) subjects. Through this, underachievement in the basic skills of mathematics could be addressed, and science and literacy introduced through more effective, innovative teaching methods.

There have been debates whether all children should learn coding skills in primary or secondary school, or if these skills should be taught only to those who aim to be programmers. Overall, computational thinking and coding skills should be basic skills for everyone who lives in the information society. Therefore, the capacities of future employees should be enhanced by introducing computational thinking skills in primary school. It is especially important to make sure that students meet the requirements of each school level and the transition points in education, such as

moving from elementary to high school and from high school to university.

To conclude, coding skills are one of the most intriguing challenges that schools, educational boards, administrations, and societies face. In this entry, ideas and examples for teaching and learning computational thinking and coding skills were provided. In addition, the importance of everyone learning coding skills in primary school was emphasized. Based on the current technological development, learning computational thinking and coding skills will be important building blocks for the school of the future.

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Teaching and Learning Process

► [IT on Teaching and Learning Process of Visually Impaired Students](#)

Teaching Computer Languages in Universities

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Synonyms

[Algorithmic language](#); [Computer programming](#); [Computer-oriented language](#); [Computing language](#); [Programming language](#); [Software development](#)

Definition

A computer language may refer to any of a variety of languages used to express a set of detailed instructions to a computer so that it performs specific tasks.

Introduction

This section will discuss a variety of issues surrounding the use of computers in universities and throughout higher education. The initial entries focus on teaching university students how to write computer programs and solve problems using algorithms.

This entry introduces computer languages, defined above as any of a variety of languages used to express a set of detailed instructions to a computer so that it performs specific tasks. Such languages are based on specific syntactic and semantic rules used to define the meaning of the programming language constructs.

Programming Overview

Various programming paradigms have emerged over time. A programming paradigm is a collection of coherent, often ideologically or theoretically based abstractions that together mold the design process and ultimately determine a program's structure (Wampler and Clark 2010; Ambler et al. 1992).

The paradigm being followed influences the program development process. There are various approaches for developing programs, including the process-oriented approach and the object-oriented approach.

Process-Oriented Approach

When using the process-oriented approach, the problem being analyzed is considered from the aspect of what processes or procedures must be performed in order to convert the provided input into the desired output. When following this approach, each program specifies a list of instructions indicating how the program's purpose is accomplished. Developing a sequence of instructions for a computer to follow involves a certain process. The problem-solving phase involves analyzing the problem and devising a general solution called an algorithm. An algorithm is simply a step-by-step outline detailing how to solve a problem in a finite amount of time. After testing the algorithm to confirm that

it works correctly, it can be translated into a programming language.

As programs become more complex, understandability can be improved if each process is considered separately. This is done by dividing the program into functions or subprograms. Each subprogram should have a clearly defined purpose and a clearly defined interface to the other subprograms in the program. This subdivision of programs can be carried further by grouping related subprograms into modules, referred to as modular design. The "divide and conquer" approach is one of the cornerstones of structured programming. Structured programming, along with its familiar features such as modular design, has long been a reliable approach to program development.

Object-Oriented Approach

One of the primary shortcomings of traditional program development techniques is their inability to easily handle the complexity associated with today's larger programs. Object-oriented (OO) development techniques are better able to cope with this complexity by offering several improved features such as data hiding, encapsulation, and polymorphism that make large programs easier to maintain and modify.

OO designs are thought to more accurately model the real world. Instead of viewing the world as a set of processes, it views the world as a collection of entities that are characterized by certain behaviors. Furthermore, OO languages make it easier to create new data types to better represent real-world objects.

The fundamental idea behind OO languages is to combine both data and the functions that operate on that data into a single unit called an object. In order to conceptualize a programming problem, the programmer determines what parts of the problem can be most usefully represented as objects, and then all the data and functions connected with that object are combined in the class specification. An object's functions, referred to as methods, provide the only way to access its data. In order to determine the value of a data item in an object, one of the object's methods must be called to read the data item and return its value.

The data cannot be accessed directly. It is hidden and is safe from accidental alteration. Data and functions are said to be encapsulated into a single entity. Both data encapsulation and data hiding are key concepts in the object-oriented paradigm. Restricting changes to an object’s data to its member functions ensures that no other functions can alter that data and therefore simplifies writing, debugging, and maintaining the program.

Language History

Both programming languages and program development techniques emerged near the middle of the twentieth century. Von Neumann’s (1945) computer architecture led to very early programming languages, which were individual machine languages designed to control specific central processing units. UNIVAC’s C-10 language, developed in 1949, was the first computer language and made use of mnemonic instructions, like “a” for add and “b” for bring. It was not long before high-level programming languages with more natural syntax became available to simplify computer programming. By the late 1950’s, universities had discovered, and in many cases created, higher-level languages.

The Computer History Museum (<http://www.computerhistory.org/>) provides a visual timeline for the creation of early languages, which is summarized in Table 1.

FORTRAN, designed to ease the translation of mathematical formulas into code, was released in 1957. ALGOL, released in 1958 and updated in 1960, introduced recursion, indirect addressing, and character manipulation, among other features. Many universities adopted ALGOL for use in their computer programming courses because it provided a precise and useful way for expressing algorithms (Keet 2004). COBOL was developed in 1959, and 80% of the world’s daily business transactions still rely on COBOL (Beach 2014). Along with BASIC, these early higher-level imperative paradigm programming languages (Wilson and Clark 1993) used global variables, assignment statements, labeled commons, and goto statements to implement increasingly

Teaching Computer Languages in Universities, Table 1 Timeline of early language creation (from <http://www.computerhistory.org/timeline/software-languages/>)

Year	Development
1945	Zuse begins Plankalkül (plan calculus), the first algorithmic programming language
1948	Shannon identifies the bit as the fundamental unit of data and shows how to code data for transmission
1952	Hopper completes the A-0 compiler
1953	Backus creates Speedcode for the IBM 701
1957	IBM team led by Backus develops FORTRAN
1958	Algol 58, intended to be a universal language, released
1959	LISP created by McCarthy
1959	COBOL created by a team representing manufacturers and pentagon
1962	Iverson develops APL
1963	First edition of the ASCII standard published
1964	BASIC created at Dartmouth by Kurtz and Kemeny
1965	Simula written by Nygaard and Dahl
1969	UNIX developed at AT&T by Thompson and Ritchie
1970	Pascal programming language introduced by Wirth
1972	C programming language released by Thompson and Ritchie

complex programs. While these early languages had subroutines, lengthy programs often featured multiple goto statements that branched throughout the rest of the code. The resulting “spaghetti code” (Conway 1978) was difficult to understand, debug, maintain, and extend (Dijkstra 1968).

In parallel, an alternate paradigm of functional programming languages evolved out of mathematical logic and recursion, with languages such as LISP released in 1959 (Turner 2012). LISP used many small isolated functions with if expressions and recursion instead of loops, allowing small portions of the overall problem to be implemented quickly and independently. Ideally, each function was implemented without any internal variables and with a single if expression similar to a mathematical formula. Each function was “side-effect free,” meaning that there were no variables or structures outside the function that were affected by actions inside the function.

While functional programming languages such as LISP were used mainly in universities, the underlying concepts of small isolated independent functions and hierarchical decomposition were included in the paradigm of structured programming languages (Dijkstra 1972; Knuth 1974) and embraced by industry (Yourdon and Constantine 1975). Software developers were encouraged to use hierarchical decomposition and structure charts (Yourdon and Constantine 1975) to create many small procedures (functions and subroutines) with no global variables. Each of these procedures performed a single task, could be tested independently of the rest of the code, and could be reused in other parts of the code while avoiding global variables. Pass-by-value parameters were used whenever possible to further isolate these routines. Procedural or structured programming languages of this period typically included PL/I, ALGOL, and C.

As early as 1960 there were over 70 languages in existence, and by 1971 there were 164 (Sammet 1972). Sammet identifies the period from 1960 to 1970 as the decade in which the programming language field matured. Higher-level languages became more widely used than machine-level coding because they made it possible to specify a problem solution in terms closer to human language.

By 1972, most universities in the USA and Australia had established computer science or data processing (which later evolved into information systems) degree programs. The majority of the computer science degree programs offered ALGOL, FORTRAN, or LISP, while most data processing programs offered COBOL. In Britain, BASIC was also widely used. During the late 1960s, departments experimented with a variety of other languages like PL/I.

The mid-1970s brought about the introduction of the microcomputer. These machines came with BASIC installed, and while that revolutionized the teaching of computer programming courses in high schools, the trend did not widely impact university programs. Instead, in the 1970s many universities adopted Pascal for use in their introductory programming course. Even as late as 1996, a survey of programs accredited by the Computing Sciences Accreditation Board found

that 36% of the responding institutions listed Pascal as their first language (McCauley and Manaris 1998). The use of Pascal in academia was eventually supplanted by other languages beginning with C and C++ and eventually shifting to Java and C#.

The 1980s continued to experience an increase in the number of available languages. Tharp (1982) reviewed several comparison studies of programming languages including FORTRAN, COBOL, JOVIAL, Ada, ALGOL, Pascal, PL/I, and SPITBOL on the basis of their support of good software engineering practices, availability of control structures, programmer time required for developing a representative non-numeric algorithm, and the machine resources expended in compiling and executing it.

The structured programming paradigm began to give way to the OO paradigm in the early to mid-1990s as languages supporting OO became widely available. The emergence of the OO paradigm accelerated more extensive use of event-driven programming. In the event-driven programming paradigm, program execution flow is controlled not by pre-defined software constructs but rather by “events” that might be generated by a user clicking a mouse, an external event from the network, or by a timer.

Additional programming paradigms have emerged over time, including relational, functional, constraint-based, theorem-proving, concurrent, imperative, declarative, graphical, reflective, context-aware, rule-based, and agent-oriented (Wampler and Clark 2010). Today’s applications, however, are seldom homogeneous and combine aspects from several different paradigms. Many complex systems consist of a variety of subcomponents that require a mixture of technologies. Therefore, using a single programming language and paradigm is becoming less common, with a movement toward multi-paradigm programming in which the heterogeneous subcomponents are each implemented with the appropriate paradigm. This may be accomplished through the use of multiple languages, an approach referred to as polyglot (“many tongues”) programming (Wampler and Clark 2010).

Multiparadigm programming can also be achieved using a programming language designed to support multiple paradigms such as C++, which supports features from multiple paradigms including classes, overloaded functions, templates, modules, ordinary procedural programming, and macros (Coplien 1999). There are also various experimental programming languages that combine multiple paradigms.

Observations

This entry has provided a brief introduction to computing languages. Subsequent entries will discuss the selection of programming languages for higher education courses, followed by teaching software design techniques in university courses, comparative languages, teaching mobile computing, informatics education, health informatics education, approaches for teaching agile methodologies, and teaching robotics courses.

Cross-References

- [Programming and Coding in Secondary Schools](#)
- [Programming Language Selection for University Courses](#)
- [Programming Languages for Secondary Schools, Java](#)
- [Programming Languages for Secondary Schools, Python](#)
- [Programming Languages for University Courses](#)

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Teaching Machines

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Synonyms

Teaching machines are mechanical, electrical, or other automatic devices that present items of information in planned sequence, register users' response to each item, and immediately indicate the acceptability of each response. The best known are from Pressey, Skinner, and Crowder and follow general principles of programmed instruction.

Introduction

A teaching machine can be considered as any mechanical device used for presenting a program of instructional material. Since antiquity, instruction has relied on machines as teaching aids (Buck 1989). Sometimes they are referred to as teaching machines, but these devices are associated with a particular type of educational purpose or activity (e.g., training soldiers). Teaching machines have a universal character, obeying a program.

According to the history of teaching machines (Stolurow 1961; Benjamin 1988; Bruillard 1997; Januszewski 2001, p. 33; Fernster 2014), Thorndike (1912) provided the rationale for teaching machines and programmed instruction.

If, by a miracle of mechanical ingenuity, a book could be so arranged that only to him who had done what was directed on page one would page two become visible, and so on, much that now requires personal instruction could be managed by print. Books to be given out in loose sheets, a page or so at a time, and books arranged so that the student only suffers if he misuses them, should be worked out in many subjects. (Thorndike 1912, page 165)

But how to create books whose contents would only be revealed at the right moment, according to the reader's understanding, as attested by the actions it would be asked to perform, when a

book gives direct access to all its contents? For this reason, it was necessary to develop mechanical or electrical machines and to design very specific books (the scrambled books).

Teaching Machines: Pressey, Skinner, and Crowder

The machine built by S. L. Pressey in 1926 is considered to be the beginning of programmed instruction. This machine consisted of a window with questions with four possible answer choices and four keys. To select one of the proposed answers, simply press the corresponding key down. If the answer was correct, the next question would appear, otherwise the original question would remain in the window and you would have to try another key until you get the correct answer. A system was in place to keep track of the various provided answers. In addition, using a simple lever, the machine was transformed into a self-test device to obtain a score that was retained (Fig. 1).

Following Pressey, other machines were developed, tested, and proven to be effective, designed



Teaching Machines, Fig. 1 Exterior of Pressey testing machine, manufactured circa 1930 (photograph by User: Gomer Bolstrood, September 7, 2006). The first testing machine (1928) had only four keys (see Watters 2015) (https://en.wikipedia.org/wiki/History_of_virtual_learning_environments#/media/File:Pressey_Testing_Machine_1.jpg)

to automatically provide feedback. Teaching machines of all kinds proliferated; since in 1936, between 600 and 700 machines had been patented in the United States (Gilman 1972). It seemed to be well established that learning required feedback, and a simple extension of this outcome revealed an interest in controlling learning through mechanisms that automatically provide feedback to the learner. One of the major weaknesses of traditional teaching, which is the gap between the student's output and the correction of his or her work, had to be eliminated. Attention was paid to the equipment, but later on, especially to the program that became the heart of the device.

The father of the programmed teaching is the American psychologist B. F. Skinner, which is part of the tradition of behavioral psychology. In his 1954 article "The Science of Learning and the Art of Teaching," he states that effective learning is based on the following principles: active participation of the subject, short sequences, gradual progression according to the student's rhythm, immediate verification, and correct answer to the question asked. He developed a teaching machine displaying the material to be learned in small pieces, ordered in a logical sequence. Each of them contained some statement with blanks or a question which required the student to construct a written response. The correct answer was given as soon as the student finished writing, giving an immediate feedback. Adopting positive reinforcement, errors were supposed to be very rare (Fig. 2).

In Skinner's school, the learner's response is an integral part of the learning process and a legitimate end in itself. Crowder (1962) represents another school, relying on differential psychology, interested in taking into account the learner's response to monitor the course. In the first case, we rely on the reward of the subject around a good answer, and error is to be avoided; in the second case, on the principle of making the student acquire mental mechanisms likely to make him/her find the correct answer, error is used to control the student's progress.

Crowder produced electrical machines for implementing his programming method called



Teaching Machines, Fig. 2 Teaching machine, designed by B. F. Skinner (https://commons.wikimedia.org/wiki/File:Skinner_teaching_machine_01.jpg)

branching or intrinsic programming. But he also produced a series of books called scrambled books. To do this, it was necessary to dissociate the logical structure from the content and the physical structure constituted by the printed pages. According to this model, many "scrambled books" have been designed, following the programming principles stated by Crowder: presentation of information followed by a question offering several possible answers, each of which is associated with a page number for continue reading (Fig. 3).

In a scrambled book, each page (or portion of a page) is a unit. The student begins in page 1, and he is asked a question to which several alternatives are given. Depending on which alternative he selects, he is directed to a subsequent page where his error is corrected or where he is introduced to the next part of the sequence.

In the middle of the 1960s, according to Ted (1965), there were about 100 models of teaching machines in various stages of development, of which about half were in limited or full production. These machines may range from a device scarcely more sophisticated than the traditional student workbook to a complex mechanical and even electronic tutor that presents not only written but audiovisual material (e.g., the Crowder Auto-Tutor Mark II).



Teaching Machines, Fig. 3 Auto Tutor, Crowder (<http://deste.umons.ac.be/cours/thappracredite/module6a-2.htm>)

Main Characteristics of Programmed Instruction

If a teaching machine presents information and questions to the user, registers the answers, and indicates whether these are correct or not, very different ways of functioning corresponding to different underlying theories are at work: linear programming with constructed response for Skinner programs (the answer is not given; the student is expected to construct it), linear programs with multiple choices for Pressey, and branching programs for Crowder. However, four main principles of programmed teaching can be underlined:

1. *The principle of structuring the subject to be taught:* the subject is broken down into elementary units; the difficulties must be fragmented according to the principle of small steps.
2. *Adaptation principle:* the progression is carried out in small steps, and the pace of progress is that of the pupil. A programmed teaching must be experienced until it “works.”
3. *Principle of stimulation:* active participation of the student, asked with questions to which he

or she must provide an effective answer, whether it is constructed or only chosen from among several proposed. This is the principle of effective packaging used by Skinner. Interactivity is a basic principle of programmed teaching.

4. *Principle of control* and immediate knowledge of the answer. New behavior is acquired more quickly if there is reinforcement.

Development of Teaching Machines and Programmed Instruction

Based on the general principles described above, programmed education has developed in many countries, in Europe and in the USSR: Pask, Landa, Talyzina, etc. (see Bruillard 1997): research was conducted, books were published (more than 300 books in programmed form in early 1970s), and lists of teaching machines were provided.

Many advantages to the use of teaching machines were underlined. They were particularly considered useful in subjects that require drill, such as arithmetic or a foreign language. Users could proceed at their own pace and also had an opportunity to review their work.

However, programmed teaching and teaching machines were heavily criticized in the late 1960s. The scrambled books are gone. Research runs up against a form of complexity barrier that is present in the most classical tasks of programmed teaching: analysis of the structure of the content to be taught, learning theories, and management of individualization.

In a desire to mechanize teaching, the computer will make it possible to go far beyond the first models resulting from programmed teaching. Dissociating the logical structure and physical structure and linking them by an addressing system led to the computers, machines adapted to this task, which also prevent possible “cheating.” Many CAL (computer-assisted learning) software adopted the model of the scrambled book.

Artificial intelligence led to intelligent tutoring systems research in the 1970s and 1980s.

Perspectives

A teaching machine is mainly a mechanical, electrical, or other automatic device that presents the user with items of information in planned sequence, registers his or her response to each item, and immediately indicates the acceptability of each response.

This is reflected in the many educational applications that can be found today on computers, tablets, or smartphones. But there is no longer a general scientific program underlying these applications. Some authors (as McRae and Bower 2013) predict a sort of rebirth of the teaching machines with new digital machines and their extraordinary capacities; the possibility to capture, treat, and analyze lots of data (big data); and the progress of IA allowing designing very detailed learning models (deep learning). An essential difference is that these machines should be able to provide personalized training for a large population. But that is another story.

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Teaching Material

- [Institutional Repositories Versus Learning Object Repositories, Challenges and the Way Forward for Higher Educational Institutions](#)

Teaching Models

- [Computing Education, Practices in](#)

Teaching Practices with Technologies

- [Blending Learning Provision for Higher Education, Integrating “New Ways” of Teaching and Learning](#)

Teaching Software Design Techniques in University Courses

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Synonyms

Architectural pattern; Design pattern; Development environment; Framework; Software architectural structures; Software architecture; Software design techniques

Definition

Software design techniques focus on reusable software architectural structures such as frameworks and design patterns used to facilitate software development. Software design techniques go well beyond both programming best practices and software design guidelines like cohesion and coupling.

Introduction

Large scale reuse of software architectures and detailed design are made possible through the use of design patterns and frameworks, respectively. Design patterns support reuse of software architecture and design, while frameworks support reuse of detailed design and code (Crawford et al. 2006).

Any academic program responsible for teaching software design concepts must continually

seek approaches by which to improve the ways in which students are prepared for the work force. Software design concepts such as design patterns and frameworks are often underemphasized in information systems and computer science curricula. “Textbooks frequently take the approach of demonstrating how to use a particular library or toolkit, spending little time discussing the structure of the program or architectural patterns like MVC” (Hanson and Fossum 2005, p. 120). The IS 2010 Curriculum Guidelines (Topi et al. 2010) state that graduates of undergraduate IS programs should be experts in high-level design of enterprise architecture. “Although the knowledge and skills that IS graduates need have recently moved significantly in the direction toward higher levels of abstraction, individual skills related to design and implementation are still essential for IS graduates” (Topi, p. 20). The Computer Science Curriculum (ACM 2013) guideline includes eight core hours dedicated to design topics such as design patterns, software architecture, structured design, and object-oriented design, but many programs fail to adequately emphasize each of those topics.

Students are often so focused on learning programming language syntax that they fail to see the big picture of applying that language to solving real problems (Hundley 2008). Development of their problem-solving skills takes a back seat to learning the minutia of a language. Thus, when students take a course in which design topics are covered, instead of focusing solely on those design topics, the instructor must spend valuable time introducing students to the concepts associated with designing a large system.

Review of Design Patterns, Frameworks, and MVC

Design Patterns

One widespread program development paradigm is the use of design patterns. Design patterns represent the embodiment of best-practice programming and support reuse of successful software

architecture and design by “capturing the static and dynamic structures and collaborations of successful solutions to problems that arise when building applications in a particular domain. Patterns explicitly capture expert knowledge and design trade-offs and make this expertise more widely available” (Crawford et al. 2006).

The use of design patterns is a fairly recent addition to software development. They were first proposed in an OOPSLA-87 Panel Session by Cunningham and Beck (1988), who in turn attribute the idea to the architectural work of Alexander et al. (1977). The concept went relatively unnoticed until the seminal piece by Gamma et al. (1993), in which they formalize the concept of design patterns and propose a design pattern template.

The concept of design patterns is elaborated upon by Astrachan et al. (1998), Hundley (2008), Reiss (1999), and Wallingford (2002). A design pattern is a documented solution to a specific problem used to guide a designer. It presents the interaction of data and methods in multiple classes, describes the implementation of classes and features needed for the interaction, and offers insight to problems that may arise in the application. Design patterns are reusable solutions that designers can apply, with possible modifications, to an application.

A design pattern is generally defined as a schema comprised of four parts:

- Name – provides a handle and a vocabulary for discussion and use of the pattern.
- Problem – provides a context in which the pattern is applicable.
- Solution – describes the components of the pattern and their interaction, including their responsibilities, relationships, and collaborations.
- Consequences – trade-offs and implications that arise from adapting the solution to the problem.

Design patterns are uniquely named and are written in a consistent format that makes it possible for designers, developers, and others to communicate using a common vocabulary

(Khwaja and Alshayeb 2015). They are typically written in design-pattern specification languages that document the abstraction detailed in the design pattern rather than capturing algorithms and data (Khwaja and Alshayeb 2015).

Over the last two decades, software professionals have embraced patterns as a means of recording and sharing expert knowledge for building software. It seems sensible that students should be exposed to this approach to design.

Experience often makes the difference between being a poor and good designer. When determining a solution to a problem, good designers rely on prior experience by relating the problem to those they have previously encountered. Design patterns are the results of formalizing this experienced-based knowledge and document the stereotypical techniques and program structures used by veteran programmers. Each pattern describes a particular scenario with constraints, motivations, and relationships and provides a relatively optimum solution to these problems (Tao et al. 2015). Recent studies by both Hussain et al. (2017) and Gravino and Risi (2017) found that there is a significant relationship between design pattern usage and greater software quality.

Shortly after their seminal conference paper, the book *Design Patterns: Elements of Reusable Object-Oriented Software* was authored by Gamma et al. (1995). The 4 authors, now known as the Gang of Four, presented 23 design patterns for purposes such as object creation, modification, reuse, implementation, and data sharing. These are used as the foundations of all other patterns. These original 23 patterns have since been expanded upon, but there are three basic patterns that are especially useful to understand. They are Singletons, Factories, and Builders.

Singletons

In a singleton design pattern, the instantiation of a class is restricted within a single object, and that object can be shared across an entire application. Singletons are useful when one and only one persistent instance of an object is needed for the entire lifetime of an application. The instance of the object is not created until it is needed. When it

is requested, a single object from the class is created and kept inside the class itself. This often is accomplished using a private constructor, ensuring that the only way to create the object is from within the class itself. This makes it possible for the class itself to make sure no more than one object is ever created.

While similar effects can be attained using a static class, static classes can have only static methods, meaning they are purely procedural. Because the singleton is truly object-oriented, it offers several advantages. For example, unlike a static class, a reference to the single instance of a singleton can be passed as a parameter to other methods, and that parameter can be treated like any normal object. Furthermore, a singleton can implement interfaces, inherit from other classes, and permit inheritance. While less competent programmers sometimes use singletons to replace global variables, this is clearly a narrow or incomplete use and often considered poor practice.

A singleton is commonly used when an application has a set of data that does not change often but is frequently referenced. Constantly returning to the data store to retrieve data that has not changed is inefficient and an extensive and unnecessary use of resources. Using a singleton, we can dramatically decrease the number of times we retrieve data that has not changed. A painter's palette serves as an analogy. It does not make sense to go back to the paint tube each time we need a color. Therefore, we would keep an instantiation of all of the different colored paints we need on the palette and only refresh them when the paint is "dirty." Examples may include a list of user permission roles, organizational categories (such as gender or age groups), or even a collection of data access layers for multiple data sources.

Factories

In a factory design pattern, objects are created without exposing the creation logic to the client. The goal is to have a single location where all instantiations of a class or series of classes are defined. The objects for these classes cannot be created on their own; they can only be requested

from the factory class. Using a constructor that has namespace access modifiers will facilitate this behavior. Factories create not only consistency in how objects are created, but it also creates a single place to go when there are problems. Rather than scouring your entire project to find each line of code in which you created a certain object, you simply go to the factory where it was "assembled" and fix the problem there. It will now propagate that fix through your entire solution. The simplest analogy for a factory is an actual factory. For example, a factory that makes gears will make a specific type of gear. If you want one of those gears, you must request it from that factory, and it will be made for you. If a problem is found with that type of gear, it is as simple as going to the factory and having them fix their error there, and all future gears from that factory will no longer have that problem. Examples for a factory may include a Roster class that is the only place where new employee objects can be created or a Messaging class where all messages sent to users are created.

Builders

You would use the builder design pattern when the construction of an object is complex or has a specific order. Builders are like factories. The main difference being that the builder pattern is used to create complex objects with lots of parts and/or when the order in which the parts are put together matters; however, factories are for less complex construction processes. A simple analogy for a builder could be a construction firm. For example, if you want a house, you might go to the construction contractor and request a house. The house will have lots of parts that they will need to construct because a house has a lot of objects that depend on other objects (inter-object dependencies). The builder's job is to put all of these dependent objects together correctly and in the right order to make this complex object that is a house. The order matters because you cannot put the roof on the house before you have erected the walls, nor can you erect the walls until you have laid the foundation. An example case for a builder may be when you need to build a report that requires particular components of the report to

be retrieved before you can retrieve additional related data.

Frameworks

Frameworks facilitate reuse of detailed design and code. “A framework is an integrated set of components that collaborate to provide a reusable architecture for a family of related applications” (Crawford et al. 2006).

A framework defines a family of related applications and contains elements that are common to those applications (Tao 2002). Frameworks provide structure by enforcing naming conventions (directories, files) and rules for constructing a system. They also provide components that aid in the construction of a system. Application developers extend the framework to build custom applications. Thus, a framework is basically a development environment in which programmers can develop applications of all types much easier and faster, including Web applications. A framework may consist of source code libraries, utilities, plug-ins, development models, and a wide range of tools, the purpose of which is to accelerate the application development pace.

There is a core of recurring themes in most frameworks (Caspersen and Christensen 2008):

- The framework delivers application behavior at a high level of abstraction.
- A framework provides functionality within a well-defined domain, i.e., frameworks address specific domains like graphical user interfaces, gaming, insurance, telecommunication, etc.
- A framework defines the interaction patterns between a set of well-defined components/objects. In order to use the framework, the developers are required to understand these interaction patterns and must program in accordance with them.
- A framework is flexible so that it can be tailored to a concrete context, provided that context lies within the domain of the framework.
- A framework makes possible the reuse of code as well as reuse of design.

MVC

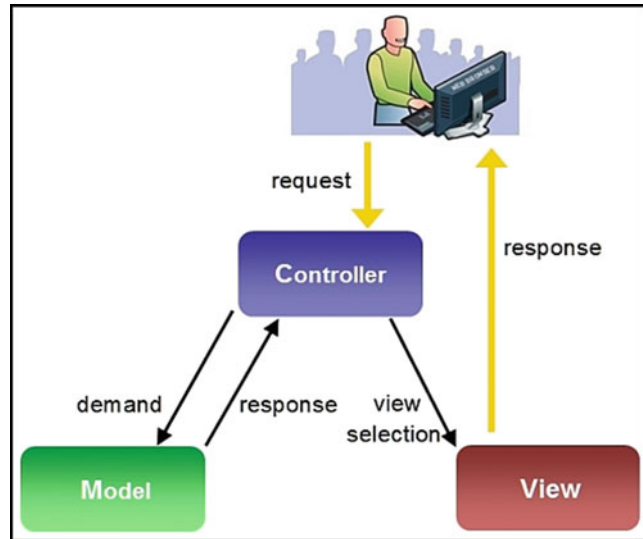
The Model-View-Controller (MVC) pattern is probably the most widely known pattern. Rather than being a design pattern, it is generally agreed that MVC is an architectural pattern. While design patterns typically focus on components of a subsystem and their relationships and collaborations with each other, architectural patterns focus on the larger subsystems of an application along with their relationships and collaborations with each other. (Note that the preceding clarification can be found with multiple attributions on the Internet.)

MVC has proven to be an important architectural pattern for facilitating the development, debugging, and maintenance of systems. The origin and details of the MVC are explained by Tao (2002), Morse and Anderson (2004), and Hanson and Fossum (2005). It was developed for Smalltalk-80 at Xerox PARC in the late 1970s as a means of facilitating the development of systems with graphical user interfaces (GUI). MVC was found to be particularly appropriate in applications that provide multiple views of the same data. It has been successfully applied to the development of client-server and web-based systems (Gacimartín et al. 2011; Kasik and Stankus 2010). MVC has been used and adopted to varying degrees in most GUI class libraries and application frameworks, and it has become the central feature of many modern interactive applications (Morse and Anderson 2004).

The key idea behind the MVC pattern involves separating user interfaces from the underlying data represented by the user interface. Thus, the MVC pattern, as shown in Fig. 1, separates the three main components of an application: Models, Views, and Controllers.

- The Model contains the data collected on the client side as well as application methods to access and manipulate the data. This includes both the information represented by the View and the application’s business logic that changes this information in response to user interaction. Data models are typically databases or XML files. The Model provides data to the other two components.

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Fig. 1 MVC patterns
(Chao et al. 2013)



- The View is responsible for the visual display of the application. The View component contains scripts that render the View selection for the user and contains all the graphical user interface components that receive input from users. In addition, the View is responsible for displaying output created by the Model for the user.
- The Controller dictates how the application behaves by acting as the primary event handler that responds to events generated by the user through the graphical components in the View. The Controller is the glue between the data models and the views. It connects the presentation (View) and data layer (Model) to each other and coordinates activities between them. Controllers process user input and update the Model and View appropriately. Every controller has a number of actions, and each action will, in general, generate a View for the user. Actions are grouped into controllers based on some criteria, generally a common data model or purpose. Every action is responsible for taking the relevant data, doing whatever controller-specific processing needs to be done, then passing it to the View.

In general, the Model manages application data, the View presents the user interface, and the Controller handles events for the View.

Separating the internal data models from the interface views that set or display the data allows models to be represented by a variety of views. Further, the model's algorithmic logic is distinct from the management of the view, thus leading to a simpler program design.

The views must maintain their own state, and there must be communication by which the models update the views or the views update the models. Such communication may be initiated by internal processes or by the user-initiated events. Events may also trigger internal processes that result in updates of the models and/or the views.

Encapsulating the three abstractions (Model, View, and Controller) into separate classes leads to multiple desirable outcomes:

- The same set of business logic (Model) can be used with multiple views to provide different user interfaces for the same underlying application. These interfaces could include web interfaces or traditional GUIs, or could be developed in multiple languages or with different sets of user permissions.
- The impact of user interface changes is minimized. The application's "look" can be drastically altered without modifying data structures and business logic.
- The reusability of domain objects is increased (Tao 2002).

- By separating the model from the view and controller, separate teams of developers can work on each component, either serially or in parallel.
- Automated test harnesses can be used to perform extensive unit testing on the business logic without tedious testing of the GUI.

The MVC pattern has proven to be very useful in industry and also can be effectively used in student projects using either traditional or object-oriented methodologies. Web applications, mobile applications, and other interactive software systems can benefit by being designed with the MVC pattern logic.

Benefits of Patterns and Frameworks

The motivation for using design patterns and frameworks is explained by Ali et al. (2011), Gamma et al. (1993), Vuksanovic and Sudarevic (2011), and Wick (2001).

Little software of any consequence is developed using only a programming language. With the emergence of modern software development methodologies and related frameworks, many developers began to harness their advantages, such as faster development, enhanced security, availability of useful and standardized libraries, simpler organization of work in development teams, and clearer structure of code due to strict conventions and use of patterns that encourage separation of domain logic, user interface, and the data processing model.

Design patterns have become an extremely effective tool with which to solve software development problems because they represent language and application independent solutions to commonly occurring design problems. Developers familiar with design structures can apply them immediately to design problems without having to rediscover them. Less experienced software developers can benefit from design patterns by taking advantage of the lessons and outcomes learned by more experienced developers. Design patterns also facilitate the reuse of successful architectures, because expressing proven techniques as design patterns

makes them more readily accessible to other developers.

Most commercial software is developed using a framework by extending and customizing the default, generic functionality that it provides. Thus, frameworks not only help in understanding and constructing real-world applications but also provide additional reusability of both design and implementation. Frameworks offer numerous technical and organizational advantages over classical development methods, such as faster development and cleaner application structure. In addition, programming using frameworks is more comfortable for developers, since frameworks provide for many common programming tasks.

The use of frameworks reduces time spent on code maintenance and future development in many ways:

- Frameworks provide numerous libraries and helpers, making it possible for developers to achieve comparable functionality with less code, so the software is more easily maintainable.
- Software unit testing, defined as a process that includes the performance of test planning, the acquisition of a test set, and the measurement of a test unit against its requirements (IEEE 1986), is facilitated by the framework rather than performed manually.
- Those tasked with software maintenance will require significantly less time deciphering existing code developed via a framework, thanks to the Model-View-Controller pattern and other coding conventions.
- Future improvements, such as protection measures against future hacking attack techniques and yet unknown vulnerabilities, may be addressed by future releases of the framework and thus may only require upgrading the framework to a newer version.

Additional Applications of Patterns and Frameworks

While patterns and frameworks improve software quality, they can also be used to address specific

needs. Esakia and McCrickard (2016) discuss the use of patterns and frameworks in the development of mobile apps. Prabhakar et al. (2017) show that the use of various design patterns in the development of various components of data mining applications can improve quality attributes such as reusability, maintainability, extensibility, adaptability, and performance. Colesky et al. (2013) and Van Niekerk and Fletcher (2015) explore how design patterns can play a role in introducing security during the groundwork of applications by influencing coding habits of developers. Suphakul and Senivongse (2017) discuss the use of privacy design patterns for the development of privacy-aware applications. A large variety of additional applications for patterns and frameworks can be discovered with an Internet search.

Motivation for Teaching Design Concepts Via Frameworks

One of the most beneficial aspects of design patterns is their educational nature. Creating a design pattern requires a high degree of explicitness. Wallingford (2002, p. 152) explains:

Writing a pattern requires the author to state explicitly the context in which a technique applies and to state explicitly the design concerns and trade-offs involved in implementing a solution. These elements of a pattern provide significant benefits to the reader, who can not only study the technique that defines a solution but also explore when and how to use it.

Astrachan et al. (1998, p. 153) assert that “patterns are an essential programming and pedagogical tool.” Wallingford (2002) agrees, calling for further studies into ways in which to use patterns effectively in teaching.

Christensen and Caspersen strongly advocate frameworks in teaching, and provide many convincing arguments for their use topic (Caspersen and Christensen 2008; Christensen 2004; Christensen and Caspersen 2002). The programming context faced by most programmers today is radically different from the one that existed a decade and a half ago. Being a successful developer is no longer a question of being a good

programmer, but just as much a question of understanding complex interaction patterns in frameworks and being able to design in accordance with their guidelines. Developing any realistic software requires the ability to identify proper software frameworks to reuse as well as the skill to write the specialized code for the task at hand.

This means that we need to teach new skills to our students in addition to the old ones. Writing even a simple program that has a graphical user interface using a framework is radically different from traditional approaches. The event-driven protocol in a framework requires students to understand the complex interplay between framework code and their own code. Students must be adequately trained to make software reuse their first development option.

While the main motivation for teaching frameworks focuses on the obvious need to teach students about the techniques that govern modern software development, there are additional pedagogical aspects that make frameworks a worthwhile.

- Student motivation: If students must program everything from scratch, then the workload and complexity rule out developing software that in any respect compares to the sophisticated and appealing programs that they are used to from, for example, the Windows platform. However, a framework used in the classroom defines the skeleton of an application that can be customized by an application developer and can provide the “bells and whistles” that makes the effort invested by the student look more appealing or “professional.” The “return on investment” is simply greater for the student.
- Setting an example: A well-designed framework can serve as an exemplary use of design patterns by making it clear that design patterns work together and that patterns really define roles.
- Gentler learning curve: Simple frameworks can illustrate basic concepts in framework theory and practice in a gentle way as stepping stone for learning more complex GUI frameworks. It is important that students learn the basic concepts and techniques relating to frameworks.

- Developing is a reuse business: Students must learn that software development entails more than producing code but also involves locating and incorporating reusable assets. Frameworks illustrate many design patterns and reinforce the concept that patterns express roles in a collaboration pattern rather than objects that are to be copied into a design. Frameworks exemplify the reuse of design as well as code, whereas design patterns demonstrate only design reuse. Thus, they serve to strengthen the concept of programming as a process of reuse as well as coding.
- Workforce ready: Frameworks have already made an impact on how industrial software is developed in a cost efficient and reliable way. Graduates should be familiar with the basic concepts and techniques relating to frameworks. Further, students are better prepared for the workforce when exposed to commercial tools.
- Object concepts. Frameworks utilize best practices of object-oriented programming. Requiring students to read and understand parts of frameworks will provide them with important insights in how to structure complex systems in a master-apprentice fashion.
- Responsibility-driven design: An MVC framework is an excellent example of how responsibility-driven design influences the identification of classes and the assignment of responsibilities to those classes. While many students have an initial expectation that the GUI should be integrated with the data since they are so closely related, an MVC framework provides an intuitive and concrete example of how the separation of manipulation and display can result in a powerful and flexible software design (Wick 2001).
- Become familiar with multiple widely used patterns and get hands-on experience developing simple applications to illustrate learned patterns.
- Develop the ability to consciously apply proper patterns in future software design efforts.

Summary

Several studies have made the case that current curricula neglect design patterns, architectural patterns, and frameworks. While many studies have established the benefits of patterns and frameworks, there is a need for additional research to find ways in which to incorporate these in teaching.

There are many benefits to incorporating patterns and frameworks in the classroom. By introducing students to patterns and frameworks during their education, they gain not only an appreciation for design concepts like separating the user interface from the underlying data and logic but also exposure to commercial software tools that enhances their future marketability.

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Teaching with Computing, Educational Games

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Synonyms

Development tendencies; Entertainment; Knowledge; Play; Serious games; Skills

Serious Games

Play is widely considered to be the most natural form of learning. According to Vygotsky, play contains all developmental tendencies in a condensed form and is in itself a major source of development (Vygotsky 1978). In an online environment, computer games provide individuals with opportunities to play. Most of these games are designed primarily as entertainment. However, some games are meant to be more than just entertainment.

Serious games include all forms of games that have a serious intention, such as *educational games*, which have the intention to impart specific skills or knowledge to the player. In many areas it is difficult to reach the youth in an effective manner which engages them in high-quality educational material. This can act as an obstacle to learning (Boyle et al. 2016). Educational games provide an important instructional medium in such areas where it is difficult to engage young learners.

Benefits of Educational Games

Educational games have many potential beneficial outcomes for learning. A review of current literature showed that the most frequently occurring outcome was knowledge acquisition. This is followed by perceptual and cognitive, affective, and behavior change. Some papers also report outcomes related to acquisition of soft skills and social skills (Boyle et al. 2016).

One of the most important aspects of educational games is the reported increased interest in the subject matter and the ability to motivate youth to learn (Petri and Gresse von Wangenheim 2017). These games provide a fun and safe environment, where students can learn from their own mistakes and practical experiences without real-world consequences. The situated learning environments of such games provide an increase in authentic context for learning, more authentic activities, access to the skills of experts, multiple roles and perspectives, opportunities to collaborate in knowledge construction, support for scaffolding, and many other benefits (Mouaheb et al. 2012).

Application Areas

Educational gaming has been used in many subject areas; however, their use is currently most popular in STEM disciplines (Boyle et al. 2016). Examples include games in many game genres, including simulation, role-playing, drill and practice, MMORPGs, strategy, puzzles, and adventure games.

Future

The use of educational games is currently experiencing massive growth. This can be attributed to the growing body of evidence for the efficacy of such games, as well as the increased availability of easy-to-use game development tools, which is driven by the large growth in the global computer game market. One can thus expect to see many more of these games at secondary school level in future.

Cross-References

- ▶ [Blended Learning](#)
- ▶ [Computers in Primary Schools, Educational Games](#)
- ▶ [Computers in Secondary Schools, Educational Games](#)
- ▶ [Educational Assessment, Educational Data Mining, and Learning Analytics](#)
- ▶ [Educational Resources, Geographical Information, Geomedia, and Learning](#)
- ▶ [Educational Resources, Hypermedia](#)
- ▶ [Game-Based Learning](#)
- ▶ [Games in Higher Education](#)
- ▶ [Games, Simulations, Immersive Environments, and Emerging Technologies](#)
- ▶ [Gamification](#)
- ▶ [Teaching Machines](#)

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Teaching with LOGO Philosophy

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Teaching with a Logo Philosophy

What is programming? In a narrow interpretation, programming means communicating with a machine using a language that it “understands.” The goal of such a communication is to instruct the machine to do what the programmer wants. Unfortunately, programming languages are often poor in their expressive power and very technical in their syntax. Many of them seem more like mysterious encodings than languages one would like to use when expressing one’s thoughts. For this reason, in the past, many programming courses failed at the stage of their introduction. It is easy to design programming courses that would frustrate almost any pupil. As a consequence, several countries excluded programming from general education.

On the other hand, in a deep and broad interpretation, programming means problem-solving, including communicating and explaining the discovered solution strategy in an exact way or to quote Donald Knuth (1996):

Science is what we understand well enough to explain to a computer. Art is everything else we do.

This is a chance for applying the basic principle of constructivism, i.e., for *learning by doing* (Piaget 1971). If a problem is viewed as a set of problem instances possessing the same abstract concept, then problem-solving can be seen as a process consisting of three phases:

- *Phase 1.* Trying to solve several concrete problem instances, one after the other, in order to gain some involved expertise in solving the problem. Constructing a solution to a given

problem instance and verifying its correctness are nothing more than learning by doing.

- *Phase 2.* When a general method to solve all instances of the given problem has been discovered, the strategy is described in a metalanguage and then in a programming language.
- *Phase 3.* The method implemented as a program is run on a computer in order to observe its behavior and to verify its correctness in terms of expected functionality. The product of that activity is a program, a *thing that works*.

All three phases correspond to constructive work. Repeating them in a loop can improve both our expertise and the resulting program. Extending the functionality of a program increases its applicability to new situations (i.e., tasks) and makes its description more understandable or its execution faster. All this can be turned into a never-ending story of improving products, just as in real live.

Why did Seymour Papert consider teaching programming as a chance for deepening and enriching the concept of classical constructivism and, as a result, introduce the term constructionism? (A discussion of the differences between the two terms is given by Ackermann (2001).)

Papert (1999) said that:

We learn better by doing. . . but we learn better still if we combine doing with talking and thinking about what we have done.

This means that humans learn by doing, reflecting about their doing, and reflecting about the products of their doing. Programming allows for reflection because it is possible to test the functionality of programs by observing their behavior and to discuss observations with others. Papert (1999) adds that:

Life is not about ‘having the right answer’ – or at least it should not be – it is about getting things to work.

Getting things to work is the critical term. *Making our products work* is the main philosophy behind this form of education and behind teaching programming using *Logo*. Papert refers to

constructionism as *learning by getting things to work*. One has to see the potential of an open end in education based on constructionism. The goal is not to learn how to apply and maybe – in a better case – to understand a specific method for solving a class of problem instances. Instead, it is possible to truly discover a method to solve a given problem. This is not about discovering a special one, but any working or even only partially working strategy, highlighting the creation of something so original that it is not described in any textbook and surprises teachers. Striving for a real-life experience enables pupils to learn about the process of searching for a solution.

An Advanced Concept of Logo as Merging Constructionism with Critical Thinking

The following more general view on teaching programming with *Logo* philosophy builds upon and enriches Papert’s concept of *learning by getting things to work* in the root of the matter. Critical thinking in education is concerned with the following (Hromkovič 2018b):

Do not teach the products of science as facts, models, or methods or, still worse, how to use technical devices. Rather teach the processes of their discovery.

In particular, this highlights the need to teach pupils:

- How to develop experience by sampling data, observing processes, and undertaking experiments (for instance, trying to solve specific instances of a given problem)
- How to formulate a hypothesis based on prior experience and how to verify its correctness
- How to use knowledge to create products with a desired functionality and how to test them under realistic conditions
- How to reiterate the previous points in order to correct and deepen the understanding and in order to improve the functionality of the products

This approach aligns with the philosophy of *getting things to work*; it focuses on supporting the growth of the pupils' expertise by running processes of discoveries and by creating things that work in an expected way.

Combining critical thinking with constructivism fits the vision of Papert (1999):

This is not a decision about pedagogic theory but a decision about what citizens of the future need to know... The rapid and accelerating change that marks our times means that every individual will see bigger changes every few years than previous generations saw in a lifetime. So this is the choice we must make for ourselves, for our children, for our countries and for our planet: acquire the skills needed to participate with understanding in the *construction* of what is new OR be resigned to a life of dependency.

Indeed, it is not possible to tell what exact kinds of jobs primary school pupils are being prepared for, since most of these jobs may not even exist yet and we are not able to forecast them at this point – just imagine a 6-year old in the early 1990s telling you she wants to be a web designer once she grew up. In more detail, future education has to pass on three essential skills to future generations. Children need:

- To view everything as a process of its evolution. To be trained to immerse into the processes of discovering knowledge and developing products for any purpose.
- Not to believe in any presented facts and models without questioning the degree of their credibility and checking the limits of their validity by following the processes of their discoveries. To understand that many things that are commonly referred to as facts merely represent an intermediate state of our knowledge and view them as a challenge to understand things better. Particularly, to be able to recognize misinterpretation and over-interpretation of statistical results. This is a common problem in most sciences that are primarily based on collecting data.
- To view products of technology through the eyes of creators, seeing their strong sides and drawbacks. To think about how products could

be improved or extended in their functionality. To be able to check their functionality by running them under real application conditions.

The concept of *Logo*, invented by Papert and colleagues (Papert 1993), fits these goals. Children gain experience by trying to draw a given geometric picture. They can do so step-by-step, by instructing the turtle to draw the shape piece by piece. This way, they notice immediately when something goes wrong, which offers the possibility to search for an appropriate fix and then continue working constructively. Making mistakes and learning from them is an essential part of the learning strategy – the true real-life learning.

Altogether, children design programs as products of their work and let them run to *discover* to which extent their functionality matches the expectations. This is pure *learning by getting things to work*. The iteration process of correcting, improving, or extending programs is deeply rooted in our past, the key of how people used to work ever since.

A very strong feature of *Logo* lies in the simplicity with which one is able to compose programs modularly. By programming, children learn how languages develop and incidentally *construct* (develop) their own programming language (Hromkovič 2018a, b) by introducing new words. Children teach new words to the computer which then they are allowed to use in their further communication with the machine. The way this can be done in *Logo* is as simple as it gets. Children learn to assign names to their programs, and then they use these names as new instructions, i.e., new words. Letting children develop their own languages is an enrichment to classical language classes, because in programming courses pupils learn to understand languages through their evolution. Later, they can also design some parts of the grammars of programming languages and, by doing this, understand the formal structure of languages even better.

Programming in *Logo* is an iterative and interactive process of constructing programs, running the resulting products, observing their execution,

and finding reasons to continue improving them. This way of learning is beneficial to all subjects of education systems. Papert (1999) phrased the following analogy about good teaching:

The best way to become a good carpenter is by participating with a good carpenter in the act of carpentering.

However, this analogy is somewhat special: in *Logo* philosophy, all problems are open-ended. For each computing problem that can be solved, there are infinitely many different programs solving it. We do not advise the pupils to discover a certain one. To this end, Papert (1999) says:

A crucial aspect of *Logo* spirit is fostering situations which the teacher has never seen before and has to join the pupils as an authentic co-learner.

Vision

Taking *Logo* as a philosophy of education, practitioners can contribute in two ways. One is to improve teaching programming in a way that still strengthens the *Logo* philosophy with the focus on constructionism. The other is to apply the *Logo* philosophy for creating concepts and learning sequences in other subjects. The two aspects are discussed in the following two subsections.

Strengthening *Logo* Philosophy by Teaching Programming

One of the main obstacles in teaching programming occurs in the phases where programming novices start to write longer programs. Frequently, teachers are overwhelmed by the vast number of

pupils requesting help in the process of searching for errors. Giving too many instructions and too much advice comes with the risk of disturbing the learning process. Moreover, the ability to find errors in programs autonomously is an essential part of a programmer's work.

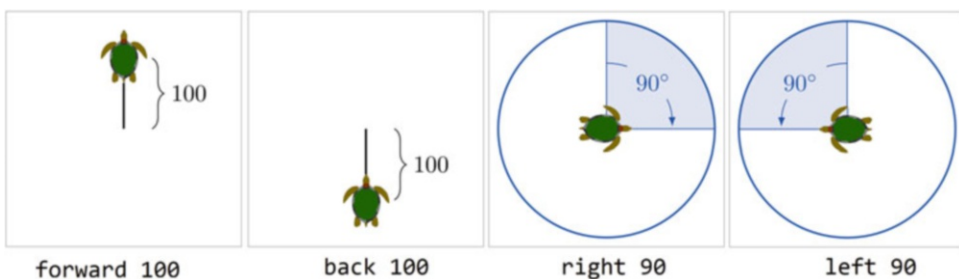
True constructionism in teaching programming means to train the pupils' ability to master the process of searching for errors and correcting them. The goal is to make children as independent as possible while *getting their own products to work*.

Programming in *Logo* primarily means to draw geometric shapes on the screen by moving a turtle. *Logo* programming relies only on four simple commands (see Fig. 1):

- Moving forward a certain distance: forward 100 or fd 100
- Moving backward a certain distance: back 100 or bk 100
- Turning left a certain angle: left 90 or lt 90
- Turning right a certain angle: right 90 or rt 90

As few as four commands are sufficient to create a wide range of different shapes such as squares, spirals, houses, or stars. In order to solve problems like these, novices need to think algorithmically: first, they think of a suitable solution strategy which then they formulate for a computer in a precise description, a program; after that, they execute their program and verify whether their strategy works as intended.

The *Logo* programming environment XLogoOnline (Hromkovič et al. 2017) is



Teaching with LOGO Philosophy, Fig. 1 Basic commands available in LOGO

designed for a young and yet inexperienced audience attending primary school. It is tailored to a curriculum (Hromkovič 2018a) that covers programming concepts such as sequences, repetition, modular program design, and parameters. With a simple and uncluttered user interface, the programming environment is designed not to induce additional cognitive load. This is important since programming is an activity that is strenuous and demanding by nature; children are prone to committing numerous mistakes. All difficulties they encounter fall in either one of two classes: *syntactic* and *logical errors*. Pupils struggling with syntactic errors fail to express their ideas in a way that the computer understands. A program with logical errors can be executed by the computer; however, it leads to unexpected behavior. The XLogoOnline programming environment supports pupils coping with challenges related to both classes of errors.

Challenge 1: Expressing an Idea Such that the Computer Understands It

Programming in a language with formal syntax and rigorous structure requires precision. Unlike humans in natural languages, computers are not able to infer meaning from incomplete or incorrect sentences in a programming language, and so they refuse to execute programs that are ambiguous or incomplete.

In order to find out what syntactic errors novices typically commit in *Logo*, an experiment with 180 novice programmers was conducted that ran for 2 h and collected a trace of more than 5000 programs. An analysis for syntactic errors showed that, after an initial exploration phase, incorrect program invocations (due to missing spaces, extraneous or missing arguments, or typos) were among the most common syntactic errors committed by novices (Forster et al. 2018).

As a result of these findings, a methodology that allows for detecting as many syntactic programming errors as possible was integrated into the XLogoOnline programming environment. As the users type, their programs are continuously and automatically checked in the background. Programs which fail to parse are analyzed further to locate errors. Syntactic flaws are indicated

immediately at their corresponding location within the program. Whenever suitable, age- and knowledge-appropriate explanations that tell the pupils how to resolve the issue are provided. This simple and yet powerful mechanism reduces the time spent searching for typos and other syntactic errors significantly, yet the children still learn about the need to express themselves precisely from a syntactic point of view.

Depending on age, typing a program already poses a significant hurdle for novices. Kindergartners, for instance, do not know how to read and write yet and thus heavily depend on spoken words and symbols. For them, programming in written form is too difficult. For this reason, block-based programming can be used until the pupils are proficient enough to work with a keyboard. In block-based programming, children snap together command blocks with semantic meaning. Blocks only fit in ways that comply with the underlying language specification, which eliminates syntactic errors altogether. Block-based programming provides a simplification that allows young pupils to program despite them not reading and writing fluently yet.

Challenge 2: Searching for Root Causes of Unexpected Program Behavior

Syntactic errors cause programs to become non-executable. This is not the case for logical errors; however, they result in unexpected outcomes due to logical flaws in reasoning. Such errors cannot be automatically detected by any computer, and, in order to recover from logical errors, children need to develop proper debugging strategies. First, a debugging mechanism is presented that was introduced into the XLogoOnline programming environment and allows for stepping through program execution manually. Second, the systematic bottom-up problem-solving approach used in a proposed curriculum is presented (Hromkovic 2018a, b; Kohn and Hromkovic 2018a, b). Together, they allow pupils to tackle complex problems and trace logical errors in their programs.

1. As the complexity of programs rises, programmers are more vulnerable to logical errors.

Initially, children execute one command at a time and can observe the effect immediately. Errors are evident and can be corrected on the fly. Later, novices start writing longer programs containing several commands that are all executed “at once.” Figure 2, for instance, shows a sequence of commands that is supposed to draw a square – it is nontrivial for beginners to identify which command caused the problem. Step-by-step, the programmer needs to retrace her or his reasoning and follow the program’s execution mentally. Keeping track of all information (e.g., the turtle’s position and orientation) is difficult and can cause pupils to give up. A stepping mechanism in the programming environment allows for tracing program execution step-by-step and for visualizing important drawing attributes such as pen width, color, and visibility. Command by command, the pupils inspect their program during its execution and hence identify errors as they occur. Figure 3 shows how pupils step through their program, searching for the exact location where an error was introduced.

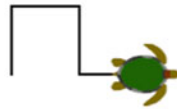
2. In order to reduce the number of logical errors in the long run, children need to approach problems systematically. This is especially important once their programs grow to a higher level of complexity, such as when they start

using self-developed commands. Reasoning about unexpected behavior in nested program calls is challenging: how is it possible to know where the problem was introduced without carefully inspecting the entire program, including all layers of indirection? Searching for errors under these circumstances is a tedious and cumbersome endeavor. For this reason, pupils can be taught a bottom-up problem-solving strategy: a given problem is first decomposed into subproblems. For each of these subproblems, the children write individual solutions and verify them by running the programs on a computer. Only once the pupils have a working solution to all subproblems do they assemble a solution to the original problem. Figure 4 shows how a grid can be constructed from a simple square that is used to draw a single row of squares and finally the entire grid.

Novices learn to test all their programs for correct functionality before nesting them in new programs. This helps at identifying and resolving errors and leads to a truly constructionist style of programming, where more and more complex structures are created while still keeping track of the underlying connections.

Teaching with LOGO Philosophy, Fig. 2 This program is supposed to draw a square. What went wrong?

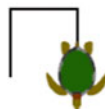
```
fd 100 rt 90 fd 100 rt 90 fd 100 lt 90 fd 100
```



Teaching with LOGO Philosophy, Fig. 3 Step-by-step comparison to check whether the visual effect matches the expectation

◀ Backward Forward ▶

```
fd 100 rt 90 fd 100 rt 90 fd 100 lt 90 fd 100
```



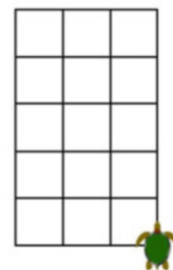
Teaching with LOGO Philosophy,

Fig. 4 Starting from a square and a row, finally the entire grid is created

```

1 to square
2 repeat 4[fd 100 rt 90]
3 end
4
5 to row
6 repeat 3[square rt 90 fd 100 lt 90]
7 end
8
9 to grid
10 repeat 5[row lt 90 fd 300 rt 90 fd 100]
11 end

```



Education Based on Logo Philosophy

For the implementation of *Logo* philosophy or of constructionism for all subjects, a series of books would not suffice. However, the point can be exemplified using mathematics. Mathematics is a language. The motivation to develop mathematics builds upon the desire to have a language with the following properties:

1. *Unambiguous interpretation of each text.* Science needs a language in which each sentence has only one meaning, allowing everyone mastering this language to communicate and understand one another unmistakably. Without such a language, there is no objectivity in science at all.
2. *Verifiable argumentation.* All argumentation in the unambiguous language of mathematics is verifiable by simply following a set of syntactic rules.

This is a starting point for designing courses in mathematics. Fundamentally, mathematics is about developing a powerful instrument for describing and investigating the world. A way to learn mathematics is to gradually discover one concept (i.e., a new word in the language of mathematics) after the other. Each new concept enriches the language and makes it more powerful as a research instrument. New concepts enable us to speak about things that could not be spoken about before and to investigate properties and relationships that could not be discovered before. From an educational point of view, it can be beneficial to discover mathematics in a continuous process of creating a research instrument to examine the real world. Mathematics takes pupils on a journey of discovering our world, and

teaching it in an appropriate way changes the perception of the subject. One implementation example is the history of designing number representations as described in a recent school textbook (Hromkovič 2018c, d).

For teaching computer science without a computer, consider cryptography as an example. This discipline is about 3500 years old and talks about secret writings. Starting with the demand for secret writings, pupils can discover one cryptographic concept after the other, develop their own secret writings, test them, combine them, learn about their drawbacks, break them, and improve them – all in a constructive way (Hromkovič 2018d; Hromkovič and Lacher 2019).

More specifically, cryptography can serve as an example of how to create a spiral curriculum, i.e., revisiting a field repeatedly, and with every iteration deepen the discussion, introducing more and more advanced insights and techniques that are at all times tailored toward the current level of the pupils. In a way, the pupils' increasing understanding of cryptography mimics the development of civilization in this respect.

With the development of permanent storage of data outside the human brain, i.e., the development of written information (which describes the first steps of *digitalization*), the need arose to hide this information from unauthorized parties. The first known cryptographic systems were comparable with what most children would come up with today when inventing secret writings with their friends. However, as civilization progressed, hiding written information meant facing more and more powerful adversaries and therefore coming up with more and more involved strategies.

For instance, in fifth grade, a lesson might start with a riddle: two friends communicate in a secret

way. The pupils are given two messages, one sent from the first friend to the second and one sent back in return; there are no further clues given, just a question of whether what the texts say can be discovered. Deciphering the messages can be done by changing the order of the letters in the texts; e.g., in the first text, the first and second letters are switched, and the third and fourth, the fifth and sixth, and so on; the second text is simply written backward. There is a wealth of possible extensions and discussions, such as coming up with other secret writings that can be broken by others (when possibly accompanied by some clues). This is pure *constructionism*.

Still in a fifth or sixth grade, it is possible to introduce other methods to encrypt a given *plaintext* by, e.g., writing it into a table of fixed size row by row and then writing down the ciphertext as the columns of the table (Hromkovič and Lacher 2019); this is essentially *scytale* (see Fig. 5).

Almost any lesson on cryptography can be made interactive while awakening the pupils' curiosity and ingenuity. And so, after having studied different ways to encrypt texts, it is possible to present the cryptosystem CAESAR (again in the form of a riddle); here, it is possible to introduce the notion of a *key* (although this concept is already present in *scytale*). In CAESAR, the plaintext is encrypted, thus resulting in the *ciphertext*, by shifting the letters of the plaintext by a fixed position i in the alphabet (starting over from A when having arrived at Z). If, for instance, $i = 2$, then any A is mapped to (replaced by) C, B is mapped to D, X is mapped to Z, Y is mapped to A, and finally Z is mapped to B; i is called the *key*. For convenience, the focus can be on the 26 uppercase letters of the English alphabet, and thus there are 25 possible keys.

While CAESAR can already be discussed in grades 5 and 6, in grades 7, 8, or 9, the pupils can start to break it. Due to the very small number

of keys, a simple brute force attack (i.e., systematically trying out all keys) is feasible, which is particularly impressive when combined with an algorithm that tries out all 25 keys and displays the resulting texts in the fraction of a second.

So how to make an encryption more secure? The answer is to have more keys. This leads to the concept of *monoalphabetic* cryptosystems where letters are mapped to arbitrary different letters. This time, there is no fixed distance between a letter of the plaintext and the corresponding letter of the ciphertext. As a result, there are not just 25 potential keys but 26; and this is quite an impressive number with 26 digits.

However, this system can be broken by taking advantage of statistical properties of the language the plaintext is written in. In typical English texts, for instance, the letter E appears most frequently, followed by the letter T, and then A. With this knowledge, the pupils are able to again decipher given ciphertexts (that should be chosen somewhat carefully). And after they see how this can be done, they can try to work on improvements by, e.g., using two different systems for different letter positions of the same plaintext.

But this is not where the spiral ends. There are numerous other systems to discover, to study, to break, and to improve. It is even possible to introduce public-key cryptography at high schools (Keller et al. 2010).

The underlying goal, however, is not to master the use of attacks on famous cryptosystems. This topic can be taught in such a way that pupils see the strengths and drawbacks of the cryptosystems presented and are thus able to design new cryptosystems based on the concepts introduced, to test them, and to try to break them. Depending on their age, the pupils become true experts for developing secret writings in an appropriate state of the historical development of cryptographic concepts. Understanding the genesis of secure

Teaching with LOGO Philosophy,

Fig. 5 Encrypting a text with a table of size 5×6

LIFE IS ABOUT
GETTING THINGS
TO WORK

Plaintext

L	I	F	E	I	S
A	B	O	U	T	G
E	T	T	I	N	G
T	H	I	N	G	S
T	O	W	O	R	K

Encryption

LAETTIBTHO
FOTIWEUINO
ITNGRSGGSK

Ciphertext

communication schemes, they gain the motivation and the ability to improve “products” of science and technology because they think in terms of development processes. And all along the way, Papert’s ideas of *getting things to work* guide the progress.

Conclusion

Teaching with *Logo* philosophy is much more than a mere example of how to use digital technology in education. It is a didactic approach linking the educational concept of constructivism proposed by Jean Piaget with the concept of critical thinking. The approach pursues the goal to educate a new generation that does not believe facts without checking how they were derived. Similarly, products of technology are not just taken for granted, but the underlying construction process is analyzed.

In this overview, some of *Logo* philosophy’s key concepts that aim at achieving the abovementioned goals are discussed. Moreover, how to enrich these concepts while still strengthening the philosophy of constructivism and critical thinking is considered.

Cross-References

- [First Programming Language in Introductory Programming Courses, Role of](#)
- [Programming Languages for Secondary Schools, Python](#)
- [Technologies in Mathematics Education](#)

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Teaching/Learning System

- [Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools](#)

Teaching-Learning Process

- [Exploratory Study Using Self-Regulated Self-Development \(SRSD\) and Technology in the Context of the Classroom](#)
- [Primary School Classroom Writing Interventions Using Technologies](#)

Team Learning

- Collaborative Learning and Patterns of Practice
-

Team-Based Simulation

- Ethics and Learning for Teacher Trainees, Team-Based Simulations in Cases of Bullying in School
-

Technological Innovation

- Different Methodological Approaches to Considering the Adoption of ICT
 - Modeling the Process of Information Technology Innovation in Education
-

Technological Innovation in ICT for Education

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Synonyms

Actor-network theory (ANT); Innovation translation; Models of technological innovation

Technological Innovation

New technologies are appearing all the time in education. Some are adopted and used in the form in which they were offered; in some cases only certain aspects of the technology are adopted, while in others the technology is rejected entirely. This problem with innovation adoption is true of all new ideas or technologies. The process of innovation involves getting new ideas accepted or new technologies adopted and used (Tatnall

2011). After the discovery of a new idea or the invention and development of a new technology, it does not automatically follow that this will be adopted by its potential users.

It is important now to distinguish between invention and innovation. While invention involves the discovery or creation of new ideas or technologies, innovation is the process of putting these ideas or technologies into commercial or organizational practice (Maguire et al. 1994). The Oxford dictionary defines *innovation* as “the alteration of what is established; something newly introduced” (Oxford 1973) and is concerned with individual and business decisions to adopt new inventions. The study of innovation does not concern itself with inventors and the details of their inventions but about individual and organizational decisions to adopt these new inventions. Invention does not necessarily invoke innovation, nor is invention necessary or sufficient for innovation to occur (Tatnall 2011).

Making any change to the way things are done is a complex undertaking and difficult to achieve successfully. The success of any innovation is always in doubt because people who are prepared to support the innovator can be difficult to find and to convince. Although writing of *political* change over 500 years ago, Niccolò Machiavelli summed this up as follows:

There is nothing more difficult to handle, more doubtful of success and more dangerous to carry through than initiating changes . . . The innovator makes enemies of all those who prospered under the old order, and only lukewarm support is forthcoming from those who would prosper under the new. Their support is lukewarm partly from fear of their adversaries, who have the existing laws on their side, and partly because men are generally incredulous, never really trusting new things unless they have tested them by experience. (Machiavelli 1515)

Models of Technological Innovation

One of the difficulties faced in investigating the adoption of technological innovations is that not all of these innovations are adopted in the form in which they were proposed – not all are adopted without change. This raises the question of just

what was adopted in each case if it was in some way different from what was proposed by its instigator. To investigate this question, it is useful to make use of one of the theories of technological innovation: the theory of reasoned action, the theory of planned behavior, diffusion of innovations, the technology acceptance model, and the unified theory of acceptance and use of technology or innovation translation. This article will concentrate on the advantages of an innovation translation approach.

Early Theories of Technological Innovation

The theory of reasoned action (TRA) (Fishbein and Ajzen 1975; Ajzen and Fishbein 1980) integrated various studies on attitude from social psychology and postulated that an individual's behavioral intention is the immediate determinant of behavior, while their attitude and subjective norm are mediated through behavioral intention, and their behavioral and normative beliefs are mediated through attitude and subjective norm.

In the theory of planned behavior (TPB), Ajzen (1991) extended the TRA by arguing that some behavior that is not under a person's volitional control might be problematic due to the differences in individuals' abilities and in external forces. The modification involved adding another construct called perceived behavioral control required to perform the specific behavior.

Technology Acceptance Model (TAM)

TAM was developed Davis and others (Davis 1989; Davis et al. 1989) for predicting and explaining adoption and use of technology. It focuses on two theoretical constructs: *perceived usefulness* and *perceived ease of use*. Davis (1986) identified major determinants of technology acceptance and, beginning with the theory of reasoned action, specified a basis for causal links between the technology's *perceived usefulness* and *perceived ease of use* along with the individual's *attitude toward using technology* and *behavioral intention* to explain technology adoption (Davis 1986, 1989).

TAM theorizes that the effects of external variables (such as system characteristics, development processes, or training) on intention to use

the technology are mediated by perceived usefulness and perceived ease of use. TAM also has strong behavioral elements and assumes that a computer user normally acts rationally and uses information in a systematic manner to decide whether or not to adopt this particular technology in the workplace. It assumes that when someone forms an *intention* to act, they will be free to act without limitation. Perceived usefulness is also influenced by perceived ease of use because if other things are equal, the easier the system (technology) is, the more useful it can be (Venkatesh and Davis 2000). TAM assumes that usage of a particular technology is voluntary (Davis 1989) and that given sufficient time and knowledge about a particular behavioral activity, an individual's stated preference to perform the activity, their behavioral intention, will closely resemble the way they do behave (Tatnall 2011).

Unified Theory of Acceptance and Use of Technology (UTAUT)

UTAUT (Venkatesh et al. 2003) was developed to provide a refined view of how the determinants of intention and behavior evolve over time in explaining IT usage behavior. UTAUT has four core determinants of intention and usage: *performance expectancy*, *effort expectancy*, *social influence*, and *facilitating conditions* to predict behavioral intention and usage behavior.

Performance expectancy, effort expectancy, and social influence are proposed to be direct determinants of usage intention, while facilitating conditions is a direct determinant of user behavior. The key moderators posited to moderate this are gender, age, voluntariness, and experience.

UTAUT was developed from the theory of reasoned action, the technology acceptance model, motivational model, the theory of planned behavior, a combined theory of planned behavior/technology acceptance model, model of personal computer use, diffusion of innovations theory, and social cognitive theory (Venkatesh et al. 2003).

Diffusion of Innovations

Diffusion of innovations (Rogers 1995, 2003) is described as: "... the process by which an innovation is communicated through certain channels

over time among the members of social systems” (Rogers 1995: 5), and so a decision not to adopt an innovation relates to the rejection of the new idea. Rogers considers the four main elements of innovation to be *characteristics of the innovation*, *the communication channels*, *the passage of time*, and *the social system*. To explain the rate of adoption of innovations, Rogers suggests consideration of the following perceived characteristics of innovations: *relative advantage* (how is technology better than one it might replace?), *compatibility* (how different is this technology to one it might replace?), *complexity* (is this new technology complex and so difficult to use?), *trialability* (can a potential user trial the new technology before adoption?), and *observability* (will a potential user be able to observe other people making use of this technology?) (Tatnall 2011). It is based on the notion that adoption of an innovation involves the spontaneous or planned spread of new *ideas*. Rogers defines an innovation as: “. . . an idea, practice, or object that is perceived as new” (Rogers 1995: 11).

Rogers considers the four main elements of innovation to be *characteristics of the innovation*, *the communication channels*, *the passage of time*, and *the social system*. To explain the rate of adoption of innovations, Rogers argues that the attributes and characteristics of the innovation itself are important in determining the manner of its diffusion and the rate of its adoption.

Innovation Translation

The view of innovation proposed by actor-network theory (ANT), sometimes known as sociology of translations (Callon 1986b; Latour 1986, 1996; Law 1987), considers the world to be full of hybrid entities containing both human and non-human elements and offers the notion of heterogeneity to help in the explanation of technology adoption (Tatnall and Davey 2003). More specifically though, innovation translation (Callon 1986b; Latour 1996), informed by ANT, makes use of a model of technological innovation which uses these ideas, along with the concept that innovations are often not adopted in their entirety but only after *translation* into a form that is more appropriate for use by the potential adopter.

Callon (1986b) proposes that translation involves all the strategies through which an actor identifies other actors and arranges them in relation to each other, while Latour (1996) speaks of how “chains of translation” can transform a global problem, such as the transportation needs of a city like Paris (or the design of a new information system) into a local problem like continuous transportation (or using Visual Basic to obtain data from an Oracle database).

Latour (1986) maintains that in an innovation translation model, the movement of an innovation through time and space is in the hands of people, each of whom may react to it in different ways: they may modify it, deflect it, betray it, add to it, appropriate it, or let it drop. He adds that this is true for the spread of anything from goods and artifacts to claims and ideas and that the adoption of an innovation comes as a consequence of the actions of everyone in the chain of actors who has anything to do with it. He suggests that each of these actors shapes the innovation to their own ends, but if no one takes up the innovation, then its movement simply stops. Here, instead of a process of transmission, we have a process of continuous transformation (Latour 1996) where faithful acceptance involving no changes is a rarity requiring explanation. “Instead of the transmission of the same token – simply deflected or slowed down by friction – you get . . . the continuous transformation of the token” (Latour 1986: 286). McMaster et al. (1997) note that innovations do not wait passively to be discovered but that each actor translates and contributes its own resources to the final result (Tatnall 2011). A translation model requires the focus to be on understanding how actor-networks are created, strengthened, and weakened, rather than on cause and effect (McMaster et al. 1997).

Latour (1996) suggests that with the translation model, the initial idea hardly counts, and the innovation is not endowed with autonomous power or “propelled by a brilliant inventor” but moves only if it interests one group of actors or another. Movement of the innovation is a consequence of energy given to it by everyone in the chain, and when the innovation does interest a new group, they transform it a little or perhaps a lot. Latour

notes that, except in rare cases, there can be “no transportation without transformation” and that “...after many recruitments, displacements and transformations, the project, having become real, then manifests, perhaps, the characteristics of perfection, profitability, beauty, and efficiency that the diffusion model located in the starting point” (Latour 1996: 119).

Longenecker et al. (1994) suggest that computer-based information systems should be regarded as complex socio-technical entities, begging the question of how this complexity should be handled. A common method of handling complexity in all subject areas lies in simplification, but the danger with simplification is that it runs the risk of removing just those things that constitute a useful description of the phenomenon under investigation by concealing the parts played by many of the actors (Suchman 1987). The question here is which details to include and which to leave out and who is to decide. In this respect, an appropriate research approach needs to ensure that complexities are not lost “in the process of labelling” (Law 1991).

In actor-network theory, the extent of a network is determined by actors that are able to make their presence *individually felt* (Law 1987) by other actors. The definition of an actor requires this and means that, in practice, actors limit their associations to affect only a relatively small number of entities whose attributes are well defined within the network. An actor is not just a “point object” but an association of heterogeneous elements themselves constituting a network. An actor can, however, in many ways also be considered as a “black box” (Callon 1986a), and when we open the lid of the box to look inside, it will be seen to constitute a whole network of other, perhaps complex, associations. In many cases details of what constitutes an actor – details of its network – are a complication we can avoid having to deal with all the time.

Supposing that some person or group has developed a new technology and wishes to get it adopted. Actor-network theory asserts that the contributions of both humans and nonhumans (technology in this case) need to be given equal consideration, so this person or group proposing

the new technology is referred to by the term heterogeneous engineer. In explaining how this process works, Callon (1986b) outlines four aspects or “moments” in the process of translation:

1. *Problematization* involves the heterogeneous engineer defining the nature of the problem so as to be seen by other actors as having the answer.
2. *Interessement* involves interesting and attracting an entity by coming between it and some other opposing entity.
3. *Enrolment* occurs through a process of “coercion, seduction, or consent” and, if all goes well, leads to the establishment of a solid, stable network of alliances.
4. *Mobilization* locks in as the solution proposed by the heterogeneous engineer gains wider acceptance through some actors working to convince others.

Essentialist Approaches to Innovation Theory

Most of these approaches to technological innovation (TRA, TPB, TAM, UTAUT, and innovation diffusion but not innovation translation) suggest that some essential capacity or “essence” (Latour 1986) is largely responsible for determining its rate of adoption. A significant problem with an essentialist paradigm like this arises if a researcher tries to reconcile the views of all parties involved in the innovation on what particular essences constitute any given actor. The difficulty is that people often see different “essential attributes” in any specific technological or human entity, and this makes it difficult for a researcher to identify and settle on the ones that allegedly were responsible for the adoption (Tatnall 2011). Consider the case of two users of a mobile phone: a builder and a teenage girl. What essential characteristic would each see in the phone? The teenage girl would typically want a small, light phone that would easily fit into her handbag or pocket. She may favor a color like pink or blue. Her main use for the phone would be sending text

messages, speaking with her friends, or looking at her Facebook account. The builder, on the other hand, may want a phone that would clip onto his belt and would certainly not want one that was pink colored. His main use for the phone would be checking on deliveries of building materials and making appointments for future jobs. One could question whether they have adopted the same thing, but of course other aspects of the phone are common. They just do not agree on its essential attributes.

As an illustration of this point, Bigum (1998) contends that the assignment of intrinsic properties to technology, and in particular to computers in an educational setting, has the effect of allocating specific roles to the people and institutions that use them. Building on an argument propounded by Grint and Woolgar (1997), he contends that essentialist accounts which distinguish between human and nonhuman elements are forced to treat the machine as something with a set of fixed, intrinsic properties and the human elements as a context within which the technology is used. The problem, he points out, is that there does not appear to be a *single* essence of computers in education upon which everyone can agree. Some educators see the computer as embodying the “future of learning technology,” some as a pointer toward “anti-schooler” discourses; others see it in terms of concerns about the deployment of technology in Western society and still others in the negative light of all that is bad about dependence on technology. Any attempt at an essentialist approach, Bigum claims, would have trouble explaining how the “essential characteristics” of a computer could be seen quite differently by these different groups. He argues instead for an anti-essentialist approach based on innovation translation from actor-network theory in which, rather than containing essences, both human and nonhuman entities constitute roles for each other and work toward the establishment of durable assemblages. Such an approach, while still allowing the technology to negotiate a role, removes the necessity to make the concession of accepting some innate property within the technology that determines its fate (Tatnall 2011).

Use of Innovation Translation to Explain Educational Adoption

The remainder of this article will concentrate on innovation translation and its use to explain adoption, partial adoption, or non-adoption of new technologies in education.

Schoolchildren Who Have Learning Disabilities

Around the world there are a significant number of school students with learning disabilities (otherwise known as special needs) who require some assistance and support in their learning. The use of ICT and the Internet has played a major role in enhancing and shaping the knowledge, skills, and self-esteem of these students (Adam 2011). The study described here involved case studies and participant observation in two outer suburban special schools in Melbourne, Australia, and also looked at the role and impact of Victorian Education Department policies on these school environments (Adam and Tatnall 2010).

Special schools are especially complex socio-technical entities and research into their infrastructure, organization, and curriculum needs to take account of this complexity. A significant difficulty arises in framing research in a situation like this that involves both technological and human actors ranging from students and teachers to software and broadband connections. When dealing with the related contributions of both human and nonhuman actors, actor-network theory (Callon 1986b; Law and Callon 1992; Latour 1996) provides a useful framework. ANT reacts against the idea that characteristics of humans and social organizations exist which distinguish human actions from the inanimate behavior of technological and natural objects, instead offering a socio-technical approach in which neither social nor technical positions are privileged.

The actors involved in the adoption of this technology to assist students with special needs were found to include the students themselves, their parents, their teachers, school principals, school ICT specialist teachers, the school council, the web, microcomputers (PC and Macintosh), software, education department policies, learning technology policy, the school

environment, classroom environments, learning approaches and paradigms, delivery methods of instruction, engagement methods, thinking processes, technology infrastructure-bandwidth, curriculum, Internet resources, digital libraries, and other related special schools. A major challenge to schools of this type is to get all these actors to form a common problematization (Callon 1986b) of their task – to all see the problem in the same way. If this can be achieved, then all the actors can work together to achieve a common goal, and ANT offers some ideas on how this might be achieved.

Special School-A is a purpose built “specialist School” providing a range of educational programs for students with special learning needs including global development delay, autism spectrum disorder, and physical, social, and emotional disabilities (Adam and Tatnall 2010). A research project over several years investigated the infrastructure to set up links between different classes at the local level. The students showed a tremendous level of enthusiasm and immediate engagement when they began to communicate via the webcams. After a good start, however, this school made less use of ICT after the school principal left.

Special School-B has a vision that encompasses a commitment to achieving excellence in education for students with additional learning needs through a curriculum which integrates learning technologies with best practice in teaching and learning (Adam and Tatnall 2010). Located on two campuses in the northern suburbs of Melbourne, School-B is a day specialist school which caters for students with mild to moderate intellectual disability between the ages of 5 and 18 years. As part of its facilities, the school is well-equipped with a Technology Center that caters for students 16–18 years of age with a focus on the development of dual pathways to cater for the diverse needs of these students. In 2006 it introduced a number of social and networked learning activities and practices with software such as Lumil, WordPressMU, ccHost, Urdit, Gregarius, and Scuttle. The school has a high level of commitment to a curriculum which integrates learning technologies with best practice

in teaching and learning in order to enhance educational outcomes for its students.

Why was School-B, in particular, successful in adopting ICT? The answer can be found in examining the actors and their interactions. Firstly the school principal (B), who was very enthusiastic about the possibilities of using ICT, developed a problematization in which his students would make educational gains. He then made use of his skill in *interessement* to convince his teachers and parents of the value of this approach and so quickly achieved enrolment. Further to this, the principal, teachers, and parents became mobilized to tell others of what the school had achieved.

Entry of Visual Basic into a University Information Systems Curriculum

In the early 1990s, Wills Institute of Technology (WIT) was located in the suburbs of Melbourne. In the early 1990s, Fred (These are not their real names) was teaching COBOL on VAX minicomputer and Pascal in MS-DOS on PCs (Tatnall 2007) but discovered that the students found that writing a program in either of these languages was quite hard going. Fred had discovered Visual Basic (VB) for MS-DOS when undertaking a programming job for a small garage. He found that he instantly liked the way that VB allowed the programmer to get to a good looking prototype solution very quickly and with much less bother than other approaches.

One of the subjects Fred had just started teaching at WIT at the time was an introductory information systems subject that required the use of a screen prototyping tool in one topic. After his recent experience with VB, Fred wondered whether some aspects of the MS-DOS version of VB could do the job. He was not interested in the programming features of VB in this, just those using its screen design. Fred could only use VB in this way by *translating* (Callon 1986b) it from a “programming language and visual programming environment” into a “screen prototyping tool,” which he did by selecting some features of VB while ignoring others (Tatnall and Davey 2001).

As the student labs had by now been equipped with new PCs with Microsoft

Windows, after this successful curriculum innovation, Fred decided to give the Windows version of VB a try in an operating systems programming subject. This subject had previously concentrated on programming within a Unix environment on the VAX, but with the growing importance of the PC and Microsoft Windows at this time, Fred thought he could well justify making use of VB to write operating system extensions for Windows instead of Unix. This involved another translation of VB to become a “language to teach operating systems programming.” This was achieved by leaving out all of VB’s visual aspects and concentrating on just those aspects of VB that related to operating systems extensions for Windows. All this would, of course, not have been possible if it had not been for the formation of a viable and cooperative VB network consisting of Fred, the introductory IS subject, the operating systems programming subject, Visual Basic, the student labs, and the students. All of these actors needed to work together cooperatively to make the adoption of VB a success.

A couple of years later, Wills Institute then merged with Burke Institute (BIT) to form Burke University of Technology. In the revised information systems curriculum of the new university, a decision was needed in choosing a programming language for a third year programming unit. It was thought that this language should address issues such as graphical user interface, client-server concepts, and possibly multiple platforms. With a little help from Fred, Visual Basic was the language chosen for this subject with another translation of VB to become “Visual Basic the language for rapid application development with databases.” The main aim of the subject was to show students how a programming language, Visual Basic in this case, could use SQL commands to interact with a database management system. After the experience of Fred’s screen prototyping subject had shown students and many of the academic staff some of the ways in which it could be used, VB was easily able to enrol many of them as allies in its attempt to become the language of choice for this subject.

Adoption of Mobile E-Training in a Factory

A large factory is keen to ensure that its workers are well trained to safely use all its new machinery and equips each employee with a tablet PC fitted with wireless networking containing delivery software and a profiling program for the particular employee. Each factory machine has its own operating procedures, and details of safety considerations are stored in the machine. As an employee moves through the factory to use different machines, this safety information is made available through wireless networking. Software on the machine recognizes the tablet PC of a new operator and automatically downloads content to this computer which configures it to what it has determined to be the learning style of the employee (Tatnall and Davey 2003). Although factory management issues each employee with their own tablet PC, encouraging or forcing them to use it is another matter. What factors determine the likelihood or adoption of this innovation?

With an actor-network analysis, the researcher would first identify as many as possible of the (human and nonhuman) actors. In this case some of these actors are obvious: factory employees, management, factory machines, learning packages, tablet PC, wireless networking, delivery software, and the profiling program. The way to proceed now is to interview the actors. While it might seem odd to speak of “interviewing” the nonhumans, this is done by looking at instruction manuals, speaking to various humans about them, investigating how, and why, they were built, and any other techniques that simulate an interview situation. We then proceed to “follow the actors” (Latour 1996) in determining what is important and what is not with the aim to discover networks of associations and interactions.

If the employer-employee relationship in this company is such that the workers are suspicious of any initiative coming from management, then this is likely to be significant. At this stage we attempt not to judge the likely consequences to potential adoption, just to note this interaction. Most of the other interactions are between the factory workers and various nonhuman actors. In common with an approach using innovation diffusion, we would

investigate how they use the machines; is this simple and straightforward, or is it difficult and clumsy? What about the interactions with each of the computer-based technologies? How does the employee interact with the learning package? Do they like using the tablet PC? Do they find carrying it around a nuisance? How does management view these technologies? Do they have any interactions with them? How did they decide on the learning package? Why did they decide to use mobile technologies rather than a training room? One difference between these approaches to theorizing innovation is that innovation diffusion concentrates more of the characteristics of the technology and TAM and UTAUT look at its perceived usefulness and ease of use, while innovation translation tries to look beyond this to investigate the human and nonhuman interactions involved.

The Victorian Education Ultranet

In Australia and many other countries, parents have traditionally been informed of their children's progress at school through the use of school reports, parent-teacher evenings, and an annual "Open Day." All parents want to know both what their children are doing at school and how well they are progressing. They want to know as much about the school, where their children spend so much time, as possible. In 2010 the Victorian Government introduced an online system, the Ultranet, for informing school communities by use of web-based technology (Tatnall and Dakich 2011). It was designed to support knowledge sharing across Victorian government schools and also to provide facilities for informing parents and for curriculum delivery and online learning and teaching (Department of Education and Early Childhood Development 2010a). The Victorian Government's Department of Education and Early Childhood Development (DEECD) described the Ultranet as "a student centred electronic learning environment that supports high quality learning and teaching, connects students, teachers and parents and enables efficient knowledge transfer" (Department of Education and Early Childhood Development 2011). The Ultranet was essentially an extended intranet/

extranet and was rolled out to all government schools in September 2010 (Tatnall and Dakich 2011). After a short and not very successful life, it was finally abandoned in June 2013.

Study of adoption of the Ultranet required looking at the contributions and interactions of human actors but also of those of nonhuman actors including the technology itself. It is important to think of the Ultranet as an actor and not just an artifact. The following human actors can be identified: state government policymakers, students (over 500,000), teachers (about 40,000), parents (about 1 million), principals of government schools (about 1,500), school councils, teacher educators, pre-service teachers, and the Ultranet developers. There are also many non-human actors: broadband connections, Web 2.0 technologies, schools, school computers, home computers, the Victorian Institute of Teaching and Learning, the emerging national curriculum, policies, privacy laws, DEECD, the Victorian Government, and the technology of the Ultranet itself (Tatnall and Dakich 2011; Tatnall et al. 2011). It is, however, not the actors themselves that are important but their interactions with each other (Fig. 1).

The problematization of the Ultranet by the government was as a system to offer access to learning materials and to inform parents of their child's progress. This seemed worthwhile to many when it was first proposed. Unfortunately not enough effort was then put into convincing teachers and parents to accept this problematization and so to become enroled. The Ultranet was officially launched in August 2010 when Victoria's 1,500 state schools were closed for an extraordinary student-free day for teacher professional development (Department of Education and Early Childhood Development 2010b). All 3,500 state school principals and assistant principals were called to Melbourne to attend Ultranet's "Big Day Out" at the Melbourne Exhibition and Convention Centre to learn about the state's new online learning network. Teachers across the state were asked to familiarize themselves with the Ultranet from their own school location, but unfortunately the launch turned into a fiasco when the Ultranet crashed disastrously



Technological Innovation in ICT for Education, Fig. 1 Ultranet – the big idea

at 9 am (Tatnall et al. 2013). The first attempt to convince teachers of the value of the Ultranet at the “Big Day Out” and student-free day for professional development was thus a failure. This attempted intersement was a disaster that, far from convincing teachers of the Ultranet’s worth, did exactly the opposite. Another attempt at intersement was in appointment of Ultranet coaches for schools, but unfortunately some coaches did not seem to understand the human issues involved in convincing teachers and parents to use the Ultranet. One coach told a school that it just had to use the Ultranet as it was DEECD policy, with no other justification. In another failure of intersement, a parent of

secondary schoolchildren pointed out that he had not been able to find out much about the Ultranet and that as far as he was aware his children’s school was not using it. Clearly there should have been a good deal more done to convince principals, teachers, and parents of the Ultranet’s value. The human aspect of promoting the Ultranet was not given sufficient consideration.

School Management Software: MySchool and CASES21

The adoption and use of school management software require a socio-technical approach as there is a need to consider both the human actors such as teachers, parents, and students and also various

nonhuman actors including school computers, administrative software, and the Internet. Administrative computer systems in schools have been designed to meet the need to handle the large amount of data relating to individual students and student groups (Davey and Tatnall 2012). In terms of ANT, however, users have no input into use of these systems with only the choice of using them in their current form, or not. There has been no possibility of translation.

A website designed by the Australian Commonwealth Government to inform parents and the community about all Australian schools is **MySchool**. Early in 2010 the Australian Government launched this e-government initiative (Gillard 2010) that contains information about all of Australia's 10,000 primary and secondary schools. The aim was to allow parents to compare schools to which they might potentially want to send their children or to see how their child's school compares with other local schools. It includes information on the number of students and teachers at the school, the socioeconomic background of the parents, and an indication of how the school is performing in national literacy and numeracy testing (Davey and Tatnall 2012). It provides information so that parents can compare their school (or potential school) with neighboring schools and with 60 statistically similar schools (Gillard 2010).

The human actors involved in the adoption of MySchool include teachers, school principals, and parents. The main nonhuman actors are schools, school computers, home computers, national curriculum policies, privacy laws, and the technology of the MySchool website. There has been no compulsion for schools, teachers of parents to adopt MySchool and also no possibility of its translation into a different form.

The MySchool website was initially seen to threaten the relationship between parents and schools by providing easy access to information about all schools and the possibility of a "league table" of the "best" schools in the country. Teachers and school principals have a profound interest in the MySchool website as potentially it could affect the number of new students wanting to attend their school and to the retention of

current students. One possible consequence of MySchool was that parents may have considered moving their children to another school if their current school's performance was below par. MySchool developers similarly recognized the power of teachers at the local level and so completely bypassed them, communicating through the public website rather than through normal school communication channels, all of which required teacher involvement. There has been a good deal of controversy about MySchool as some schools consider that they have been unfairly treated and that as a consequence they have lost potential students. Others have argued that the methodology for obtaining and showing the data is flawed.

CASES21 (Computerized Administrative Systems Environment in Schools) was built to provide a clear single means of gathering the data required by government from schools. In the past, in a large centralized system such as the Victorian Education Department, keeping track of what schools were *really* doing was very difficult. In particular getting consistent financial data from schools when they each had their own accounting system was almost impossible (Birse 1994). This is why an early version of CASES was initially introduced in the mid-1980s and mandated for use in all Victorian government schools. The prime purpose of the latest version, CASES21, is to enable reporting from schools back to the Department of Education, rather than to directly assist schools with their own administration (Birse 1994; Tatnall 1995). CASES was developed as a tool for overall school administration and as a means whereby schools reported back to the Department of Education (Tatnall 1995).

Here the human actors include teachers, school principals, school administrators, teacher educators, and the CASES21 developers. The nonhuman actors include broadband connections, Web 2.0 technologies, schools, school computers, policies, privacy laws, school councils, the Victorian Department of Education and Early Childhood Development, the Victorian Government, and the technology of CASES21.

Most teachers, except those in administrative positions, have little direct interaction with CASES21 other than making use of its output. They do not tend to make suggestions for improvement (translation) to CASES21 as they think that these will not be given serious consideration. CASES21 has an impact on parents to the extent that the system provides them with fast access to important information (from the Education Department) through a single system, but they only have access to its output in the form of lists and reports. School bursars and other administrative staff make considerable use of CASES21. It has had a large effect on how they perform their work, but as it is a closed system, they are not able to have any effect on it. There is no possibility of translation.

One Result of Project Management Training

IT organizations and organizations with IT Departments frequently procure project management training as part of their initiatives to improve business outcomes through professional education (Lecomber and Tatnall 2014). As project management has evolved as a field of practice, organizations have realized that their entire business, including most of the routine activities, can be regarded as a series of projects. The Business Directory (2017) defines a project as a: “Planned set of interrelated tasks to be executed over a fixed period and within certain cost and other limitations.” Simply stated, all organizations are managed by using projects (Kerzner 2014), and this is even more so in the development of information systems. Since the Australian Computer Society included IT Project Management in its Body of Knowledge for Computer Professionals (Tatnall and Reyes 2005), most Australian universities now include one of more IT Project Management subjects in both undergraduate and postgraduate degrees. In most cases this involves practical work using case studies and software packages such as Microsoft Project to formalize these concepts. As well as IT Project Management education in universities however, there is also substantial industry professional training in project management.

A research study was conducted by Lecomber (2017) to understand how participants used and adopted the PRINCE2 methodology for workplace projects following a professional training course. Projects in Controlled Environments version 2 (PRINCE2) is a methodology for managing projects and has grown to become a de facto “standard” as a project management method in more than 150 countries worldwide (Sargeant et al. 2010; AXELOS 2015). The PRINCE2 methodology was developed for the UK Government to manage their IT projects and was based on soft systems methodology (Checkland and Scholes 1991; Finegan 1994; Sargeant et al. 2010; AXELOS 2015).

The study workplace consisted of a number of departments, one of which was an IT department. IT staff participated in the professional training program which consisted of staff drawn from the various departments across the organization. The results showed that there were some participants who adopted as much of the PRINCE2 methodology as they were able for their work projects and actively sought to improve their practice. Another group of participants had knowledge of the methodology but considered the overhead in using it far outweighed the benefits derived from this. To analyze these two different forms of adoption, innovation translation, informed by actor-network theory, was used. Innovation translation has the advantage of being able to explain examples of partial adoption and of situations where what is actually adopted differs from what was proposed (Tatnall 2009). This was particularly relevant for this study as it could be said that one group of participants made *only* a partial adoption.

Some of the participants adopted as much of the PRINCE2 methodology as they were able for their projects and actively sought to improve practice. The study named this adoption as the Performing Translation (**PT**). Those who had adopted **PT** had a focus on continuous improvement in their practice. They are people who keep attempting to apply their learning and hence learn more. In addition, those who adopted the **PT** conducted their own research into “best practice” outside of work hours.

The other group of participants who had knowledge of the methodology but considered the overhead in using it far outweighed the benefit derived from doing so formed the Knowing Translation (**KT**). A **KT** sees nothing in the formal structures of PRINCE2 that is so valuable that they would sacrifice early delivery by going through procedures stated in the methodology. Those who had adopted the **KT** would only apply what they had learned to the workplace if they perceived adoption across the organization.

In the case of **PT** participants, as their organization did not have supports such as strong leadership for using a methodology and a strong project management office (PMO), some participants who adopted the **PT** eventually resigned from the organization. In this research study, the PMO was weak and could not enforce the governance needed to support the use of PRINCE2. Participants whose form of adoption was the Knowing Translation (**KT**) had knowledge of the project management methodology but considered the overhead in using it too great. The lack of support from the top-down commencing with the senior leadership team and the original sponsor of the methodology had a strong influence on those who adopted the **KT**. A senior leadership team and sponsor must go beyond paying lip service to the methodology and actively comply with the methodology in terms of behaviors, responsibilities, and expectations of their role on the project as sponsors and project board members.

In this study, the emergence of these two possible adoption outcomes – these two translations – has implications on how organizations derive value from their investment in professional project management education and training. As well as ensuring that the project management training is performed well, it is important that organizations commit to supports in place such as a strong PMO, senior leadership support, and strong visible support from the sponsor if the organization wishes to derive value from the project management training. Otherwise the investment in training is a waste of money. This is particularly important in the education of IT professionals.

Conclusion

This article has described a number of approaches to theorizing technological innovation in various forms of education and training. It has illustrated some of the significant advantages of using an innovation translation approach to the theorizing of innovation adoptions in education. Despite this, however, it is far too simplistic to suggest that innovation translation offers a better approach than innovation diffusion, TAM, or UTAUT to theorizing innovation in *all* situations. Many studies have shown the explanatory value of innovation diffusion, particularly in relation to large-scale adoptions such as (to offer some samples from Rogers (1995)) bottle-feeding of babies in the third world, the diffusion of modern maths in Pittsburgh, diffusion of the news, and the diffusion of a medical drug.

It might be suggested that the relationship between these types of approach, innovation diffusion on the one hand and innovation translation on the other, has something in common to that between the macro- and microelements of Newtonian and quantum mechanics in physics. While quantum mechanics is needed to explain what goes on when fundamental particles and atoms interact, for everyday occurrences Newtonian mechanics is quite suitable. Likewise I would suggest that while actor-network theory and innovation translation better explain the detail of how individuals and specific organizations adopt technological innovations, innovation diffusion does a good job in explaining large-scale adoptions.

Cross-References

► [Ultraset](#)

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Technological Teaching Knowledge

► [Restructuring Teachers' Knowledge for Teaching with Technologies with Online Professional Development](#)

Technologies in Mathematics Education

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Synonyms

[IT/ICT in mathematics teaching and learning](#)

Introduction

The use of (digital) technologies in mathematics and in mathematics education is related but not the same. Already in ancient times, people used “machines” like the abacus or the soroban to support doing calculations. And, from the seventeenth century onward, the inventions of mechanical calculation machines and electronic calculators or the use of computers or smartphones aimed at sparing people the tedious trouble of calculating in mathematics.

Obviously, in mathematics education, where acquiring calculation skills is still an important objective, each of these inventions sets of a discussion on the admittance of the device in mathematics classrooms (i.e., Waits and Demana 2000; Herget et al. 2000). Now, there is more or less an understanding that the use of technology in mathematics classrooms depends on the situation. Only what is an appropriate use for a given situation is still and will always be a topic discussed among mathematics teachers, educators, and education researchers. There are countless projects and research papers on more or less successful

uses of technology in mathematics learning. In meta-studies, Hattie (2008) or Tamim et al. (2011) describe only low impacts of the use of technology on learning outcomes and even specifically for mathematics education. Li and Ma (2010) find only small positive effects of technology on mathematics achievement (p. 225). There seems to be some relationships between the use of technology, the mathematical achievement, and the teaching approaches. The more the teachers/schools tend to constructivism, the higher the impact of the technology (Li and Ma 2010, p. 228). So, to understand the appropriate use of technology in mathematics education, both the technological tools and the pedagogical approaches to mathematics teaching and learning have to be considered.

The Executive Summary of the NCTM “Principles and Standards for School Mathematics” states the role of technology in mathematics learning very well:

Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning. Students can develop deeper understanding of mathematics with the appropriate use of technology. Technology can help support investigation by students in every area of mathematics and allow them to focus on decision-making, reflection, reasoning, and problem-solving. The existence, versatility, and power of technology make it possible and necessary to reexamine what mathematics students should learn as well as how they can best learn it. (NCTM 2000b, p. 3)

The use of technology in mathematics education should always aim at fostering the understanding of mathematics and allow students to “do mathematics” and not only save them from doing calculations. Therefore, the aspects of good mathematics teaching and helping students understand mathematics, always in relation to the use of technology, will be discussed in the next entry. Descriptions of the different technological tool types and their potential for learning mathematics will follow.

Pedagogical Aspects of Mathematics Learning

All over the world, the mathematical content usually taught in schools is rather similar. The topics

covered in mathematics classrooms are typically arithmetics, measurement, geometry, algebra, calculus, linear algebra, data analysis, statistics, and probability.

For all of these topics, there are software tools covering more or less the content taught in schools. So, if the objectives of mathematics education would just be calculation and geometrical construction skills, nobody would still need to learn mathematics, because the technological tools will always be faster and better. But mathematical understanding based on mathematical knowledge and mathematical processes is considered necessary for every educated person. Mathematical competencies allow a person to solve problems using mathematical methods. An important part of mathematical competency is the knowledge when and what type of mathematical technology to use for solving the problem.

At the beginning of the century, “mathematical processes” or “general mathematical competences” were introduced in mathematics curricula all over the world. One reason were the TIMSS (Third International Mathematics and Science Study) (<https://timssandpirls.bc.edu/>) and the PISA (Program for International Student Assessment) (<http://www.oecd.org/pisa/>) studies. Because the test items in both studies not only covered mathematical skills but also the application of mathematics to solve – previously unknown – problems and to use mathematical modeling to solve realistic problems. At the same time, the educational standards and curricula of many countries became available due to the dissemination through the World Wide Web. The mathematics education communities took up to describe mathematical processes, which all students should be able to perform.

There are different names and sometimes different categorizations of these mathematical processes, but from a broader point of view, they are surprisingly similar. A reason for this similarity might be that doing mathematics is very global and intercultural. So, for the purpose of this entry, the categorization of the National Council of Teachers of Mathematics (NCTM 2000a) is used. For each process, a typical example is given, where technology is used.

Problem-Solving

Problem-solving means much more than just working on a mathematical task. It refers mainly to solving problems where the student does not know the solution method beforehand. Therefore, the students need to think of new ways to apply their mathematical knowledge. This is much more demanding than just doing, for example, algorithmic calculations.

The NCTM defines the “Problem-Solving Standard” as to enable students to:

- build new mathematical knowledge through problem solving;
- solve problems that arise in mathematics and in other contexts;
- apply and adapt a variety of appropriate strategies to solve problems;
- monitor and reflect on the process of mathematical problem solving. (NCTM 2000a, p. 52)

Example: Calculation of compound interest

Compound interest means that you have a certain amount of money, which is placed at a bank. On this deposit the bank gives you some interest, i.e., 3% p.a. (per year). If you leave the deposit and the interest in your account, the amount increases exponentially. To answer questions regarding the time needed to accumulate a certain amount of money the typical mathematical solution would use a logarithmic expression. But this problem can also be solved using a spreadsheet.

Samantha wants to invest 5000 € at a bank where she gets 4% p.a. She won't need the money in the next years so she can leave the amount and the interest in the account. How long will it take to double the initial investment?

Figure 1 gives the solution of the problem using a spreadsheet.

As the input line shows, the calculation follows directly the given situation: Each year the previous amount is kept on, and the simple interest for the previous amount is added. After setting up the spreadsheet like this, you only have to pull down the lower right corner of the cell until the amount exceeds the 10,000€.

	A	B	C	D
1	Starting Amount		5,000.00 €	
2	after year	1	5,200.00 €	
3		2	5,408.00 €	
4	Interest Rate	3	5,624.32 €	
5	4.00%	4	5,849.29 €	
6		5	6,083.26 €	
7		6	6,326.60 €	
8		7	6,579.66 €	
9		8	6,842.85 €	
10		9	7,116.56 €	
11		10	7,401.22 €	
12		11	7,697.27 €	
13		12	8,005.16 €	
14		13	8,325.37 €	
15		14	8,658.38 €	
16		15	9,004.72 €	
17		16	9,364.91 €	
18		17	9,739.50 €	
19		18	10,129.08 €	
20		19	10,534.25 €	
21		20		
22		21		
23				

Technologies in Mathematics Education, Fig. 1 Example problem solving ‘compound interest’- solution using a spreadsheet

The answer in this case would be: *After 18 years the starting amount has doubled.*

Without technology the calculation would have to be done by hand, which would take too much time or using the logarithmic formula

$$K_n = K_0 \cdot \left(1 + \frac{p}{100}\right)^n \Rightarrow n = \frac{\log K_n - \log K_0}{\log \left(1 + \frac{p}{100}\right)}$$

which, for example, in Germany is not part of the high school curriculum anymore.

Reasoning and Proof

Reasoning and proof are the typical ways for mathematicians to find the truth of statements or more formally of theorems. Introducing this most immediate mathematical process in the school curriculum does not mean students have to grow into experts giving formal mathematical proofs. Reasoning and proof means here to explain why solutions are

correct or mathematical statements are true and on which conditions these solutions/statements are allowed. Considered from the other way, if school mathematics evades this process, how could they claim to do mathematics? If students never learn to ask for reasons why something is true or working and to appreciate mathematical reasoning and proof, their only source for mathematical truth or correctness would be the teacher and the textbook.

The NCTM defines the “Reasoning and Proof Standard” as to enable students to:

- recognize reasoning and proof as fundamental aspects of mathematics;
- make and investigate mathematical conjectures;
- develop and evaluate mathematical arguments and proofs;
- select and use various types of reasoning and methods of proof. (NCTM 2000a, p. 56)

Example: *Construct a triangle and connect the midpoints of the sides to form an inscribed triangle. What do you observe in regard to this inscribed triangle?*

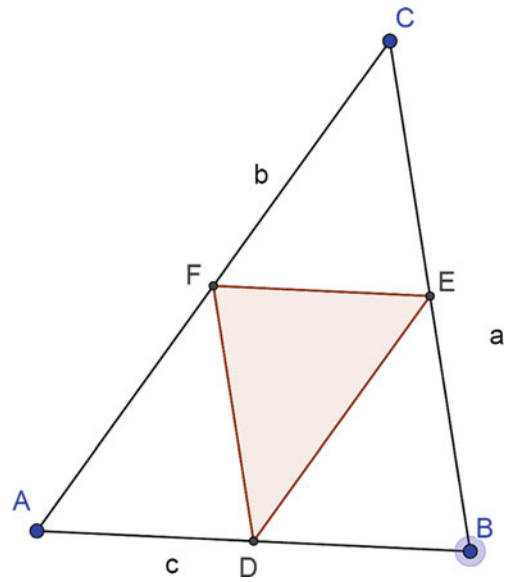
Write down your conjectures. Explain why your conjectures are true.

Using a Dynamic Geometry Software (DGS), students construct the triangle and the mid-triangle using the “midpoint” feature (Fig. 2).

Some possible conjectures students might come up with are:

- The big triangle is split into four small triangles.
- The mid-triangle is similar to the big triangle.
- The area of the mid-triangle is the fourth part of the area of the big triangle.
- The four small triangles are congruent to each other.
- The construction is an application of the intercept theorem.

To explain why the conjectures are true, students could use the intercept theorem with the intersection point C of the two lines AC and BC. Because CF is half the length of CA and CE half the length of CB per construction and then because of the “reversed intercept theorem,” the lines FE and AB are parallel. Following the



Technologies in Mathematics Education, Fig. 2
Example reasoning and proof ‘mid-triangle’ - DGS configuration 1

intercept theorem, the length of the segment FE is half of the length of the segment AB. This holds for all sides of the mid-triangle. Therefore, the triangle DEF is similar to the triangle CAB.

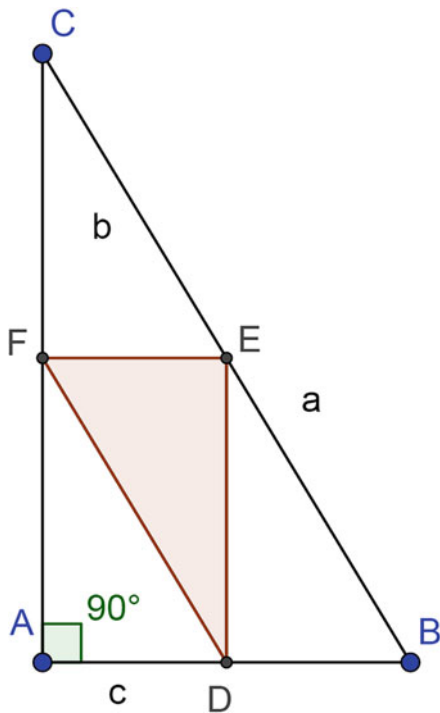
The reasoning – or if put more formally even the proof – could be done in the same way just using paper and pencil.

The use of the DGS allows the students to observe what happens to some properties of the construction, if, i.e., the point C is moved and therefore the shape of the triangle changes. This helps to distinguish random phenomena from phenomena inherent to the mathematical situation.

Another possible state of the DGS construction shows Fig. 3.

In this case there is a right angle at the point A. This is definitely a very special case. But, in this specific state, it is quite obvious that the triangles ADF and EFD complement each other to a rectangle. Because of the common diagonal – and the rectangle properties – the two triangles must be congruent.

This could help some students to get the idea of checking on congruent or similar figures, which could set them on the way of sound mathematical reasoning.



Technologies in Mathematics Education, Fig. 3
Example reasoning and proof ‘mid-triangle’ - DGS configuration 2: special case

Communication

Communication is, contrary to common beliefs, a very important part of doing mathematics. So is a mathematical theorem only then proven, if it is published and the mathematical community approved the proof, which means they did not find any faults in the reasoning of the author – yet. For learning mathematics, the use of language (oral, written, symbolic, etc.) is even more important. Because mathematical constructs like a tangent, parallel lines or recurring decimals only exist in the mind. For students to understand these constructs, they have to build their own mental models. And for this communication is essential.

Since technology is often designed to enable communication and interaction in any fields, this is also true for mathematics education. Mathematical reasoning is in itself a form of communication.

The NCTM defines the “Communication Standard” as to enable students to:

- organize and consolidate their mathematical thinking through communication;
- communicate their mathematical thinking coherently and clearly to peers, teachers, and others;
- analyze and evaluate the mathematical thinking and strategies of others;
- use the language of mathematics to express mathematical ideas precisely. (NCTM 2000a, p. 60)

Example: *Write a computer program to calculate the greatest common divisor (GCD) of two numbers.*

Some possible programs in pseudocode are shown in Table 1.

Technologies in Mathematics Education, Table 1 Example communication ‘computer program to calculate the greatest common divisor’ (All examples are taken from https://en.wikipedia.org/wiki/Euclidean_algorithm, retrieved on 2017/10/01, 12.33. The original sources are Knuth (1997), p. 318ff (division and subtraction versions) and Stillwell (1997), p. 14 (recursive version).)

Division-based solution	<pre>function gcd(a,b) while b ≠ 0 t := b; b := a mod b; a := t; return a;</pre>
Subtraction-based solution	<pre>function gcd(a,b) while a ≠ b if a > b a := a - b; else b := b - a; return a;</pre>
Recursive solution	<pre>function gcd(a,b) if b = 0 return a; else return gcd(b, a mod b);</pre>

To write computer code in whatever computer language, the mathematical ideas behind the concepts have to be understood, and the programming requires to be very precise.

Connections

Mathematics is applied in many different contexts in our world. Without mathematics, neither our society nor the technology would work. Most people do not realize this fact but think mathematics is something done in school or used by engineers. So the application of mathematics in real life has to be addressed in mathematics classrooms. Another aspect is that based on everyday situations, mathematical models can be understood. A typical example is buying vegetables, which can give an idea about the mathematical concept of proportional functions: The more potatoes you buy, the more you have to pay.

Finally, mathematical fields (e.g., algebra and geometry) are connected to each other, and techniques or problem-solving strategies of one field can be applied in another. There are even specific software to support this connection like most Computer Algebra Systems that show diagrams and even dynamic geometry features and vice versa.

Realistic situations usually come with “uncomely” numbers, so technology is often needed to do the calculation.

The NCTM defines the “Connections Standard” as to enable students to:

- recognize and use connections among mathematical ideas;
- understand how mathematical ideas interconnect and build on one another to produce a coherent whole;
- recognize and apply mathematics in contexts outside of mathematics. (NCTM 2000a, p. 64)

Example: *Find the maximum of the function*
 $f(x) = x \cdot (1 - x) \cdot e^x$.

Using a Computer Algebra System (GeoGebra) yields this answer: (Fig. 4)

The connection between the algebraic expression and the graph is obvious. In a calculus

classroom, students might be able to find the maximum using paper and pencil, but the graph would be very difficult to draw precisely.

Representations

As seen in the above examples, mathematics can be represented in very different forms. The different representations of functions i.e., verbal, algebraic, numeric, and graphic are an important topic in school mathematics. Depending on the question, some forms are better for solving problems than others, and sometimes only a change from one representation to another helps.

The NCTM defines the “Representations Standard” as to enable students to:

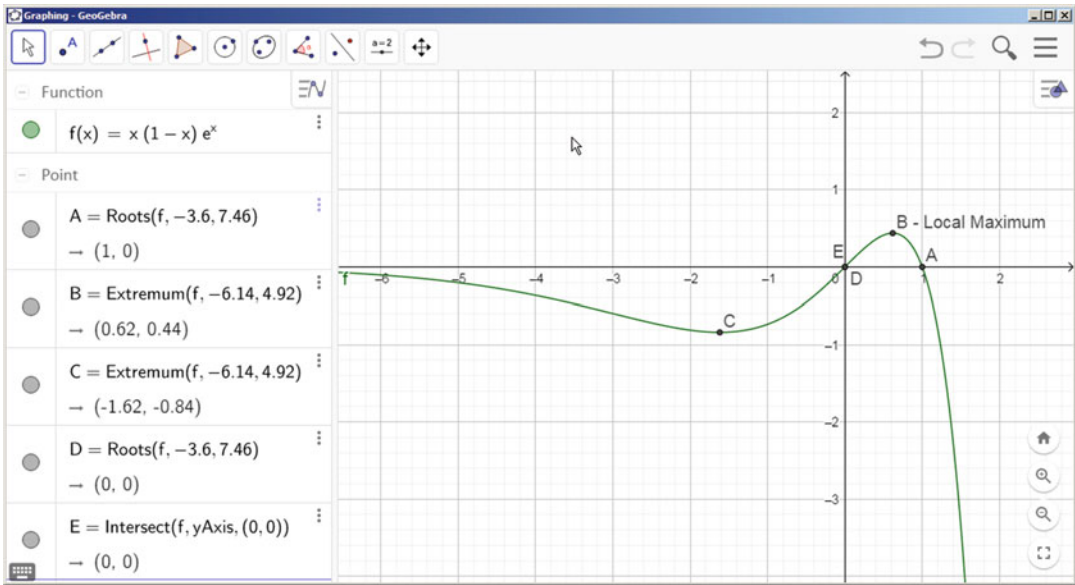
- create and use representations to organize, record, and communicate mathematical ideas;
- select, apply, and translate among mathematical representations to solve problems;
- use representations to model and interpret physical, social, and mathematical phenomena. (NCTM 2000a, p. 67)

Example: *Find the line of best fit given the data.*

In mathematics classrooms, this question is usually answered using the “least squares method,” a standard approach in regression analysis. There are numerous programs and applets in the internet allowing students to solve this problem experimentally. One is part of the NCTM Illuminations (<http://illuminations.nctm.org/Activity.aspx?id=4186>) website (Table 2).

This is only a very short overview over mathematical processes in mathematics education where the use of technology opens up new possibilities. How acquiring each of the processes works as well as the use of technology supporting the development of the general mathematical competencies are intensely worked on research areas.

In mathematics education, the pedagogical aspects should be decided on first and after that only the question arises, whether to use technology at all and if yes, for what purpose exactly. The next section addresses the main types of technologies used in mathematics education.



Technologies in Mathematics Education, Fig. 4 Example connections - 'maximum of the function $f(x) = x \cdot (1 - x) \cdot e^x$ ' using a CAS

Specific Tools

The following section can only give a very superficial glance at the types of technological tools used in mathematics education. For one thing, there are new tools developed permanently, and on the other hand, nobody can know all the available tools. Since many of these tools are initiated or even developed by teachers or school-related projects, very often the tools are only available in the mother tongues of the developers and are not very well maintained. Another phenomenon is the coalescence of the different types of tools, i.e., the combination of Computer Algebra System, Dynamic Geometry Software, and spreadsheet functionality as in GeoGebra (<https://www.geogebra.org/>).

The (non-)mentioning of specific software or websites is not in any case an indicator of the quality of the software but due mainly to the personal history of the author. Usually educational research groups, ministries of education, and

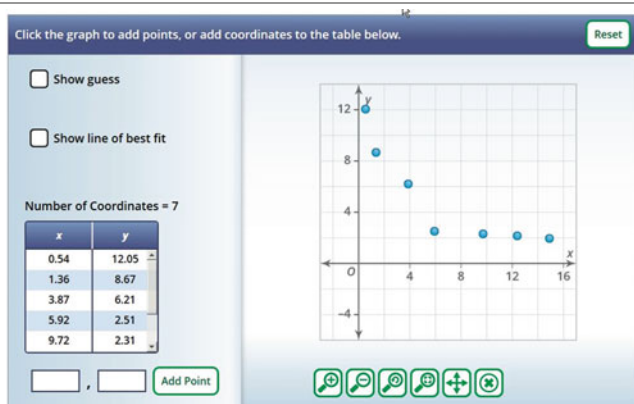
organization involved in “good education” offer country-specific lists of available technological tools.

Virtual Manipulatives

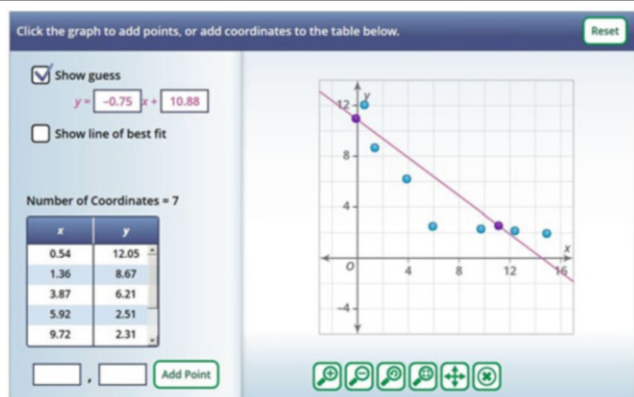
In preschool and primary education, hands-on manipulatives are used to understand the number system and the basic operations like addition, subtraction, multiplication, and division. Later on, other manipulatives like geometrical solids or pattern blocks or construction tools (i.e., compasses or protractors) are introduced. Supplementary the use of virtual manipulatives often as apps on tablets is increasing. As with all manipulatives, their use in classrooms needs a teacher with a lot of expertise, because they are not self-explanatory and sometimes can lead to misconceptions. Figure 5 shows an example for base ten blocks, used in primary school when numbers up to 10,000 are introduced.

The advantages of virtual manipulatives are the fact that they do not get lost and that there are

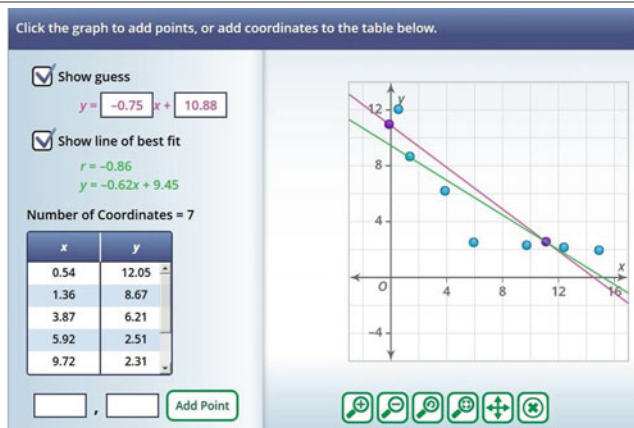
Technologies in Mathematics Education, Table 2 Example representations ‘finding the line of best fit’ (Source: <http://illuminations.nctm.org/Activity.aspx?id=4186>)



Here the points are just added in the coordinate system. Measurement data resulting from an experiment can be added via the coordinates

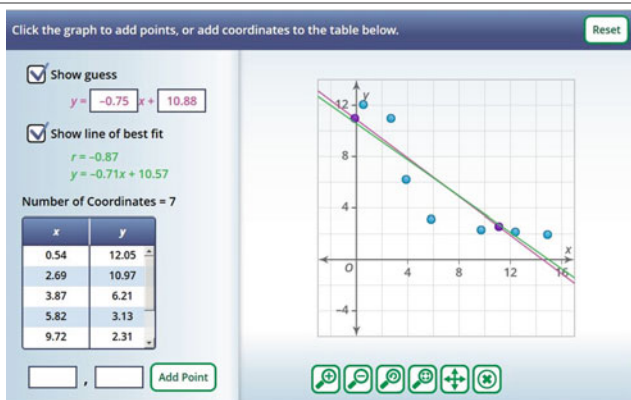


The student then “guesses” the best fitting line by moving the two points which define the straight line



Then the line of best fit according to the regression analysis is shown. Students could now change their guess accordingly

(continued)

Technologies in Mathematics Education, Table 2 (continued)

More interesting would be the question which point of the given data has to be moved where to, to make the guess a better fit

Of course, you would need some experience with finding the line of best fit, to predict the necessary movement correctly. But this is exactly a situation where the three different representations facilitated by technology allow a deeper mathematical thinking than without

always enough of them available – if there are enough devices. The handling is mostly very easy and sometimes even better suited for small children than hands-on materials.

Some of the virtual manipulatives even allow feedback or manipulations, which are impossible in real life. An example of impossible building blocks (<http://www.fisme.science.uu.nl/toepassingen/28432/>) in geometry is shown in Fig. 6.

Spreadsheets

Spreadsheet software like Microsoft Excel or Openoffice Calc are not primarily meant for mathematics education; their main use is the presentation of numbers and the creation of diagrams. In mathematics classrooms, these tools can be used like in everyday life, i.e., for cost planning calculations or generating diagrams.

They can also be used for very simple worksheets giving automatic feedback using the “if function” shown in Fig. 7.

Due to the structure using cells, spreadsheets are a very well suited for discrete mathematics. Also, functional attributions using variables and even recursive equations can be used easily as shown in Fig. 1. Using the advanced features of

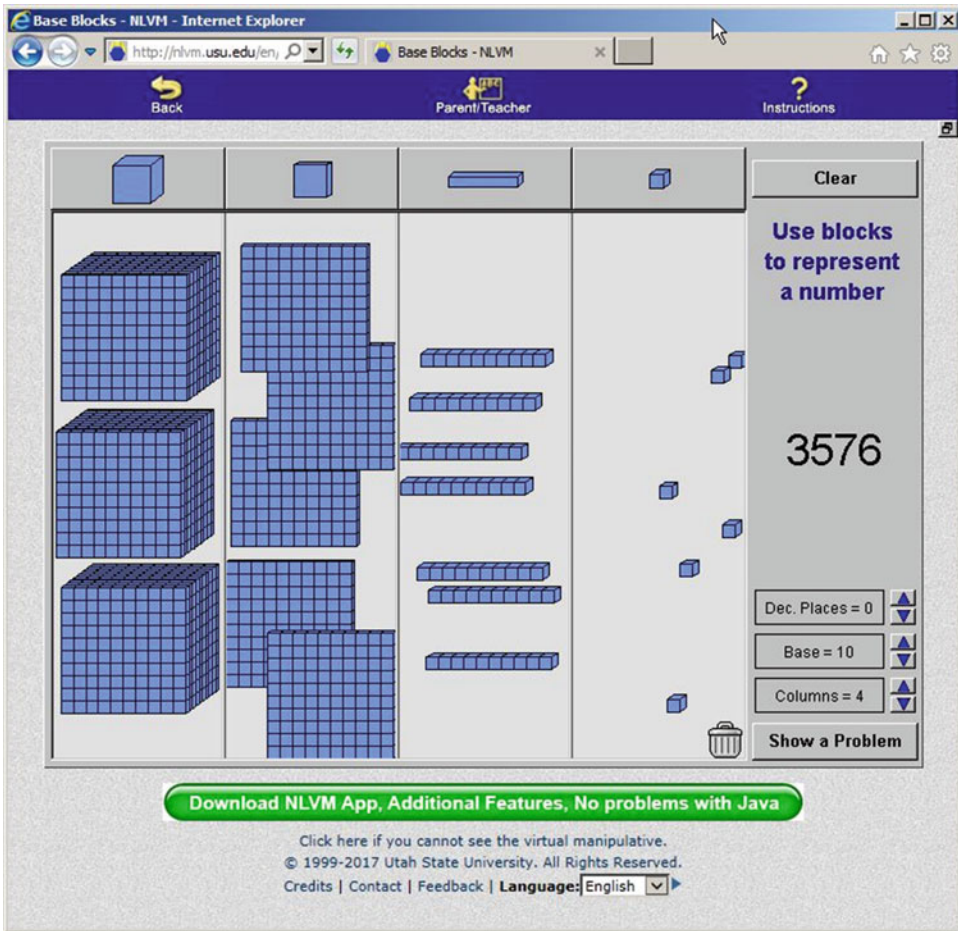
spreadsheets like a scroll bar, the Excel solver – optimization methods – or VBA programming spreadsheets can be extended to complex interactive learning environments. Nowadays even graphic calculators have some spreadsheet functionalities implemented, i.e., to create a table of values.

A non-free extension of spreadsheets is the software “Fathom” (<http://fathom.concord.org/>). Fathom is specialized to do data analysis and statistics adapted to the typical high school curriculum for statistics and mathematical modeling.

Dynamic Geometry Software (DGS)/ Interactive Geometry Software (IGS)/Dynamic Geometry Environments (DGEs)

Dynamic Geometry Software, developed in the late 1980s especially for geometry classrooms, was based originally on the geometry using only compass and straightedge (ruler). Meanwhile a lot of different features, e.g., measuring of lengths, angles, and areas, were added.

The main advantages compared to “normal” drawing software are:



Technologies in Mathematics Education, Fig. 5 Example of virtual manipulatives base ten blocks (Source: http://nlvm.usu.edu/en/nav/frames_asid_152_g_1_t_1.html?from=category_g_1_t_1.html)

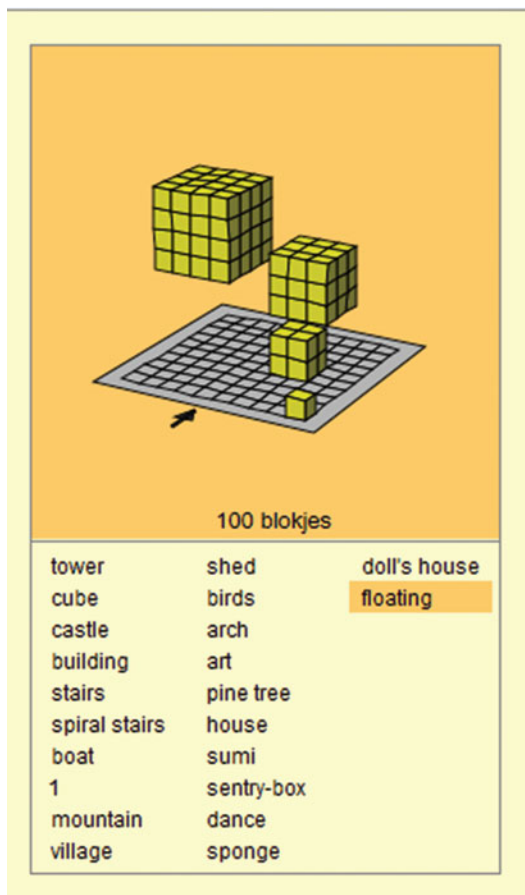
- The ability to vary already generated constructions (“drag mode”)
- The possibility to create loci if constructed points are varied using the tracing mode (“loci functionality”)
- The reusability of already created constructions (“modular construction”)

An example (<https://www.geogebra.org/>) for the use of tracing to create a locus is shown in Fig. 8. There two points A and B and a segment CD were selected randomly. Then two circles

with the same radius – the length of the segment CD – were drawn around the two points A and B. One of the intersection points (E) was traced, while the length of the segment CD was varied. The red line of all the possible places of E is the locus – the perpendicular bisector of A and B.

Of course, the interactive or dynamic feature is the main issue, which cannot be demonstrated in a printed book.

Some well-known DGS are Geometer’s Sketchpad (<http://www.dynamicgeometry.com/>),



Technologies in Mathematics Education,
Fig. 6 Example virtual manipulatives impossible building blocks (Source: <http://www.fisme.science.uu.nl/toepassing/28432/>)

GeoGebra (<https://www.geogebra.org/>), Cabri-Géomètre (<http://www.cabri.net/cabri2/accueil-e.php>), Cinderella (<https://cinderella.de/tiki-index.php>), and many others.

The classical DGS were only meant to work in the Euclidean 2D geometry with some exceptions like the projective or hyperbolic geometry (Cinderella). About 10 years ago, DGS expanded into the third dimension. Nowadays 3D versions (Cabri-Géomètre 3D (<https://cabri.com/en/cabri-3d/>)) or additions (Geometer's Sketchpad,

GeoGebra) are available. Figure 9 shows an example of spatial geometry – a perpendicular triangular pyramid. Here the main advantage is the possibility to rotate the construction and to select different viewpoints.

Computer Algebra Systems

Computer Algebra Systems (CAS) like Maple (<https://www.maplesoft.com/>), Mathematica (<https://www.wolfram.com/mathematica/>), MATLAB (<https://www.mathworks.com/>), or the open-source version Maxima (<http://maxima.sourceforge.net/>) are tools for the manipulation of symbolic and numerical expressions and are used mainly at university level and in scientific or engineering contexts. CAS can solve equations symbolically and give i.e. the derivation or the integral of functions. For school mathematics, these tools are much too powerful, but there are versions adapted to the needs of mathematics classrooms. GeoGebra (<https://www.geogebra.org/>) has also extended features of a CAS suitable to high school mathematics. The main application of CAS in schools is the use of this software in graphic calculators especially in programmable graphing calculators.

Figure 4 gives an example on how to use CAS in calculus. The introduction of this software at the end of the 1980s led to a very heated discussion about the need for change of the typical mathematics classrooms where students were focused on acquiring the skills to manipulate algebraic expressions often without deeper understanding (Herget et al. 2000). The shift of the focus in calculus in the last 20 years toward mathematical modeling was a consequence of the introduction of CAS in mathematics teaching.

Programming Languages

In the 1970s, Seymour Papert (1980) and others introduced programming into mathematics education in primary schools. Most of the groups from all over the world taking up these ideas followed a constructivist teaching approach. Their aim was to

	A	B	C
1	Complete the missing entries in the table!		
2			
3	Example: 2% = 2/100 = 1/50 = 0,02		
4			
5	Percentage Rate	4%	
6	Hundredth fraction	5/100	☹
7	Reduced fraction	1/25	☺
8	Decimal number	0,4	☹
9			
10	Percentage Rate	2%	☺
11	Hundredth fraction	2/100	☺
12	Reduced fraction	1/50	
13	Decimal number	0,5	☹
14			
15	Percentage Rate		☺
16	Hundredth fraction		☹
17	Reduced fraction		☹

Technologies in Mathematics Education, Fig. 7
Example spreadsheet with automatic feedback

use programming, at that time with the languages Logo or BASIC, as a “thinking tool.”

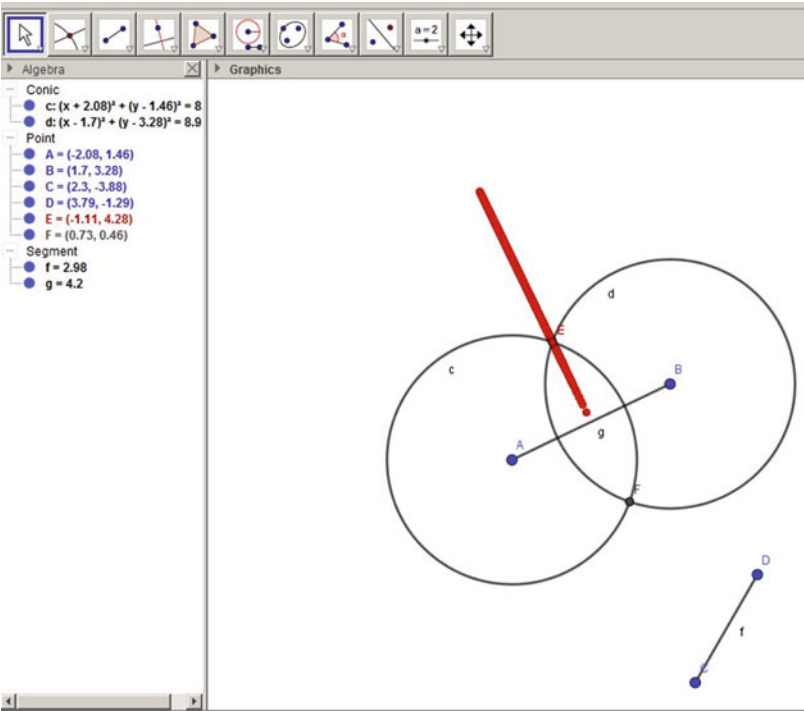
Figure 10 shows an example of a Logo program to draw recursively a binary tree with the length 150. Programming or rather the program’s reaction is used to let students check their mathematical concepts or mental models and to develop them further.

Recently new projects take up these ideas of programming in primary mathematics classrooms using the language Scratch (i.e., Benton et al. 2017).

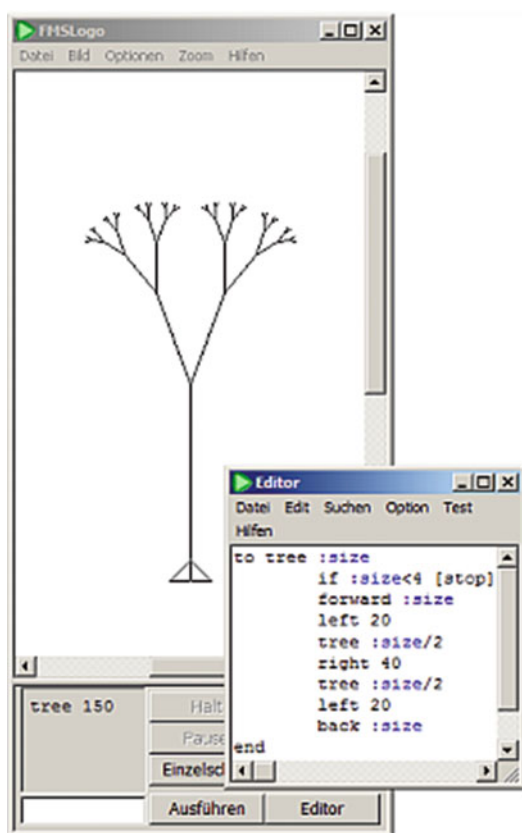
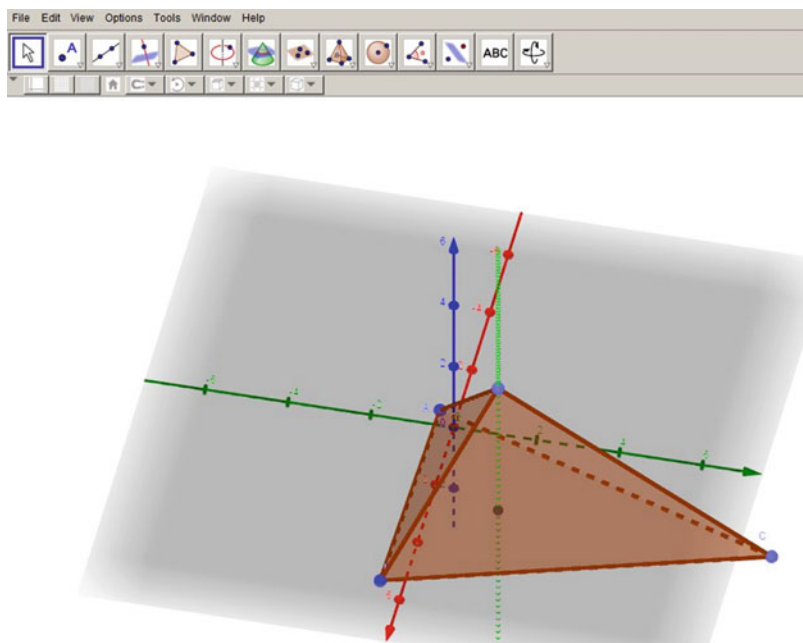
**Learning Environments/Intelligent
Tutorial Systems/Apps/Specific
Applications**

For a long time, learning environments for all age groups and mathematical topics have been created both commercially and open sources. Usually the technical features are the same as in learning environments generally, except the math-specific parts, which consist more or less of the abovementioned technologies. In addition, probably due to an affinity of mathematics teachers to

Technologies in
Mathematics Education,
Fig. 8 Example Dynamic
Geometry Software loci
functionality using
GeoGebra



Technologies in Mathematics Education,
Fig. 9 Example 3D
 Dynamic Geometry
 Software using GeoGebra



Technologies in Mathematics Education, Fig. 10
 Example programming in logo binary tree using FMS
 Logo (Source: <http://fmslogo.sourceforge.net/>)

programming, there are countless little applications available in the World Wide Web for some specific mathematical aspect. These are often very helpful to give students the opportunity to explore mathematical questions or to practice their skills. A great collection can be found at <https://illuminations.nctm.org> or <http://www.bbc.co.uk/education> and on many other sites.

Further all the mathematical topics covered in schools and even most of university level are available in the World Wide Web as scripts, Wikipedia entries, or YouTube videos.

Conclusion

Technology and mathematics education are deeply intertwined and have a long history as well as a promising future together. The main message is that always the pedagogical questions regarding mathematics teaching and learning have to be considered first and the technology in mathematics classrooms is just there to support mathematics learning and understanding.

Cross-References

- [Algorithmic Thinking in Primary Schools](#)
- [Classroom Use, Blended Learning](#)
- [Computers in Secondary Schools](#)
- [Implementation of ICT in Secondary Schools](#)
- [Mathematics Education and Technology](#)
- [Programming and Coding in Secondary Schools](#)
- [Teaching with Computing, Educational Games](#)
- [Technology Enhanced Learning](#)

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Technology

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- [Information and Communication Technologies in Chilean Schools, from Enlaces to the Present Day](#)
- [Science Education and Technology](#)

Technology Acceptance

- [Adoption of Innovative ICT-Enabled Systems for Analysis- and Intuition-Styled Teachers in Primary Schools](#)
- [Situative Perspective and Determinants of Technology Acceptance in Educational Technology](#)

Technology Acceptance Model

- [Different Methodological Approaches to Considering the Adoption of ICT](#)
- [Predicting ICT Skills and ICT Use of University Students](#)

Technology Enabled Teaching and Learning

- [Flexible and Distance Learning](#)

Technology Enhanced Learning

- [WalkAbout Framework for Contextual Learning Through Mobile Serious Games](#)

Technology Leadership

► [Information Technology for Local Education Authorities and School Districts, Use of](#)

Technology-Aided Attention Training

► [Assisting Students with Attention Deficit Disorder Through Technology](#)

Technology-Aided Self-Regulation Training

► [Assisting Students with Attention Deficit Disorder Through Technology](#)

Technology-Enhanced Learning

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Synonyms

[E-learning](#)

Introduction

Technology-enhanced learning (TEL) is concerned with using technologies to support learning whether the learning is local (i.e., on campus) or remote (at home or in the workplace). Historically, these technologies have included instructional films, radio, and television (Westera

2010), but in the current day, technology-enhanced learning pertains more to the use of computer-based technologies, including smartphones and other smart devices.

Learning can be considered as a process whereby the learner accesses concepts and ideas, assimilating these through practice and ultimately demonstrating mastery. Enhancements of learning seek to improve parts of this practice and process. With the progress of technologies, such enhancements are achieved through the facilitations of fundamental activities of learning by technology in various forms. Thus, what technology-enhanced learning ultimately offers are scalability, flexibility, and new methods of facilitating learning.

Recent applications and developments in TEL have displayed a wide variety of approaches including computer-based learning, courseware, m-learning, virtual learning environments, immersive learning environments, computer-based assessment/e-assessment, open learning, and collaborative technologies. This entry will consider the history and development, as well as the effectiveness of various approaches, of technology-enhanced learning.

Definition

Technology-enhanced learning (TEL) does not have a precise definition but instead encompasses a wide range of information and communication technologies that have been applied to teaching and learning (Kirkwood and Price 2013). “E-learning” was previously used to describe these technologies; however, definitions for “e-learning” also differed with definitions being generally classed into technology driven, delivery system oriented, communication oriented, and educational paradigms (Guri-Rosenblit and Gros 2011).

In view of the fluidity of definitions, it would be useful to define “technology-enhanced learning” as being any computer-based technology that supports learning.

Advantages of TEL

There are several advantages of technology-enhanced learning. In the research literature, studies usually describe these advantages in terms of operational improvement, quantitative change in learning, and qualitative change in learning (Kirkwood and Price 2013).

Operational improvement refers to enhancements that improve the learner's experience with the learning resources. Many studies (Copley 2007; Taylor and Clark 2010) that describe this enhancement note that technology-enhanced learning provides better accessibility to the learner compared to the conventional resources.

Meanwhile, quantitative changes in learning look at improvements in the learner's knowledge after technology-enhanced learning intervention has been carried out. Typically, this is done through pre- and posttest questionnaires, and the enhancement is quantified by looking at the difference in score between these two tests (Salkind 2010).

Qualitative changes in learning are concerned with skills developed by the learner because of technology-enhanced learning. These skills include higher-order thinking skills, reflection, and increased interaction between students (Kirkwood and Price 2013).

Pedagogical Concepts of TEL

Technology-enhanced learning is a useful tool for teaching and learning. In the wake of increasing use of technology-enhanced learning, "new" pedagogical concepts have been identified and developed. These concepts have informed educators in their development of effective practices in the use of technology-enhanced learning.

Several practices have been identified as effective practices in online learning which include (Bailey and Card 2009):

1. Encourage contacts between students and faculty in and out of classes.
2. Learning is enhanced when it is more like a team effort than a solo race.

3. Active learning is encouraged in classes that use structured exercises, challenging discussions, team projects, and peer critiques.
4. Students need appropriate and timely feedback on their performance to benefit from courses.
5. Learning to use one's time well is critical for students and professionals alike.
6. Communicate higher expectations.
7. Provide a diverse delivery system.

Computer-Based Learning/Computer-Aided Instruction

Computer-based learning emphasizes the use of a computer as the platform for delivery. In the research literature, a variety of terms are used to describe this pedagogy such as "computer-based," "computer-assisted," and "computer-aided." However, they generally involve the same concept of being based around the use of a computer.

Computer-based learning is probably the widest category of technology-enhanced learning since most technologies currently use the computer as a means for processing and delivering the information to the learner. As such, most other technologies are essentially subsets of computer-based learning. In terms of their use in the classroom, computer-based learning has been on the rise in recent years. Meanwhile, in institutions of higher learning, students are assumed to be computer literate, and much of the learning material is disseminated through the computer by platforms such as courseware, which will be discussed in the next section.

There have been many studies considering the effectiveness of computer-based learning compared to conventional methods. Most studies concluded that computer-based learning is at least as effective or more effective than older, more conventional, methods. Passey (2013) in his qualitative meta-analysis review of studies found that learners using computer-based learning or computer-aided instruction (CAI) perform better than those receiving traditional instructions. This may be one reason for the increased adoption of computer-based learning,

especially by institutions of higher learning in recent years.

Multimodal Learning

Multimodality is a concept that considers the many distinct modes (various digital media formats) deployed to communicate with each other and to express various forms of external knowledge or content. Growth in digital formats of media, and accompanying accessibility to multimedia, has lent itself to effective use of multimodal applications in classrooms.

Contributions of multimodal content, especially affecting various forms of sensory stimuli affording student engagement, could be important for design of learning environments with multimodal resources. Many different learning approaches in terms of distinctive stimuli could be applicable for students in the present context of technology-enhanced learning (Passey 2013): *visual*, static images or videos used as educational resources; *auditory*, podcasts or audio input of videos; *kinesthetic*, handling interactive content on touch-enabled displays and in augmented and virtual reality object manipulation, involving motor skills; *social*, social interaction and discussion with peers or lecturers or others through face to face (F2F) or through social learning platforms like Facebook/Chat; and *interpersonal*, learner-learner or learner-facilitator interaction through either chats and discussion in virtual learning environments (VLEs) or shared documents (e.g., Google docs) or online voting/polling applications (Clickers) as discussed in the next section.

Multimodality characterizes intercommunication strategies in expression of the textual, aural, oral, spatial, and visual resources or modes (Murray 2013). The generative theory of multimedia learning (Mayer 1997) proposes that active learning involves the cognitive processes of integrating the various sensory stimuli (as outlined above), e.g., integration of related words (verbal) and images (visual) into coherent verbal and visual models for the mind. As an example, learners, as in medical students, tend to integrate information from various different related sensory

modalities as above, e.g., heart sounds with an image of a beating heart or verbal (explanation of a presentation) with nonverbal information (watching Microsoft (MS) PowerPoint slides of the same presentation) to asking questions and giving feedback to students into one meaningful experience.

Whether a student is a single preference learner or a multimodal learner (having at least two or more modes involved in learning) in the learning environment, the presence of various sensory media approaches can allow the flexibility in learning for varied student cohorts (Sankey et al. 2010). The variety of different digital technologies and media forms provides opportunities for teachers and mediators to integrate them into practice and design a balanced curriculum (Passey 2013). Topic-specific resources and software such as simulations and visualizations can support literacy, numeracy, motor skills, and widening understanding in the short-term and in the long-term (Shieh 2012).

On the aspect of effect of different media formats, Passey (2013) found from previous studies that learning gains were maximum for audio followed by text, text with graphics, video, and physical resources in decreasing order. In order to incorporate such multimodality in learning, equitable access to multiple resources, furniture as well as the computer hardware for accessing the digital resources, needs to be present within easy reach of all students. Hence, learning spaces need to be appropriately designed, affording multimodal representation of learning resources. One such design is the technology-enhanced learning environment (TELE).

Technology-Enhanced Learning Environment (TELE)

TELE has been defined by the Joint Information Systems Committee (JISC) as a specialist area that encompasses “virtual and physical technology-enhanced learning environments (incorporating physical learning spaces, institutional virtual learning environments, personalized learning environments and mobile and

immersive learning environments” (JISC 2011, para 1). Technologically-enhanced classrooms, a term more commonly used in academic settings, have varied in terms of information technology (IT) arrangements, which may differ among different classrooms (Vartabedian 2002).

TELEs are widely endorsed to “create new opportunities in teaching and learning by integrating networking, computers, and audiovisual technology” (Vartabedian 2002, pp. 4–5). Many such technology-enhanced classrooms commonly incorporate a combination of the following: liquid crystal display (LCD)/light emitting diode (LED)/light application by stimulated emission of radiation (LASER) projector and projection system; networked desktop computers or bring your own device (BYOD) wireless connections; stereo sound and microphone system; touch screen control; document camera; etc. These technologies are incorporated within a classroom that allows in more recent cases in many countries of group seating of students in a large flat floor space (Sen and Passey 2013).

TELE is becoming a useful arena for knowledge creation activities as it provides an “information-rich environment in which the student has control in discovering knowledge, but the discovery is supported and scaffolded by extra guidance functions, which provide support and feedback for subsequent learning” (Laurillard 2002). It can create a social space, supporting flexible interaction and simultaneously affording a comprehensive suite of multimodal resources. Such applications of TELE have now been the focus for incorporating active learning strategies within technology-enhanced classrooms.

Online Polling Applications/Clickers

Clickers or classroom/audience response systems (CRS) are handheld electronic devices or, as increasingly used nowadays, online cloud-based applications accessed through mobile telephones and used to elicit anonymous student responses to questions using electronic on-screen presentations. The results of students’ responses are also immediately displayed allowing instructors to

gauge the level of understanding of their students and allow students to reflect on their knowledge of the concept at hand (Sullivan 2009). Such technologies are a part of TEL that allows a valid and effective tool to identify various levels of students’ learning through evaluation (Sen 2012) and has been found to have good predictive value, usability, and benefits in a curriculum focused on interaction. There are a large number of such online polling tools that use either simple formats of quizzes or various forms of questions (Poll Everywhere) or even encouraging team-based competitions (Kahoot!).

Courseware

A subset of computer-based learning, courseware is a platform which delivers learning materials to the learner. Courseware was previously distributed by compact disk-read only memories (CD-ROMs), but newer initiatives such as the Massachusetts Institute of Technology (MIT) OpenCourseWare have also been developed as an application of courseware.

Courseware essentially offers a platform for educators to supply learning materials to the learner, be it via tutorials, lectures, or reading materials. Through these functions, courseware has the benefit of enhancing the accessibility of learning resources to the learner since the learning resources can be easily accessed by the learner using personal computers and devices.

In schools, courseware can be bundled with a textbook as an add-on that the teacher and student can choose to utilize. These have in the past typically taken the form of a CD-ROM attached to a textbook which the student can insert into a computer with a CD drive in order to run the application. In recent years, courseware in textbooks has taken the form of a code, which the student can enter into the publisher’s website in order to access additional features of the textbook. Through this, educational materials can be made available to the learner on demand, and the learner is free to learn at his or her own pace.

Newer applications of courseware include the aforementioned MIT OpenCourseWare, which is

a website where many of the tutorials, lectures, and reading materials from university courses are uploaded online allowing anyone to be able to learn from these courses.

M-Learning

M-learning or “mobile learning” is where the delivery platform is a mobile device (e.g., laptop, smartphone, tablet). With the advent of increasing versatility of mobile devices, many of the functions that previously could only be performed by a dedicated personal computer are now able to be performed by these mobile devices.

Many educational applications (apps) have been developed for mobile devices for schools. Some notable examples include Duolingo for language learning or the popular Khan Academy for various self-learning modules. Quizlet is a flashcard mobile app for practice of a variety of topics. More and more of these m-learning apps are gaining acceptance globally such that many of them now include foreign language support, images, and audio as well as encouraging social learning with the ability to share learning (flashcards in Quizlet) with friends. These serve to complement the classroom learning experience though social and out of class “anytime anywhere” learning.

Virtual Learning Environments

Other applications of specialized m-learning include applications in virtual reality and augmented reality, since mobile devices serve as easily available platforms that incorporates technologies including a camera with capabilities to connect to the web as well as use the audio and video within one device.

Virtual learning environments (VLEs) refer to “the components in which learners and tutors participate in ‘on-line’ interactions of various kinds, including on-line learning” (Weller 2007). Virtual learning environments can incorporate portals that provide access to learning support facilities, including course information,

communication (forums, messaging, announcements), course content (lecture notes and sources), and assessment and feedback.

Virtual learning environments allow for direct communication between the educator and the learners on an individual and group basis through messaging. Virtual learning environments also typically have the added capability to facilitate discussion between the educator and learners via online forums.

In recognition of the advantages of virtual learning environments, there is increasing adoption of virtual learning environments by many institutions of learning. Common proprietary systems used by these institutions which employ VLEs include Moodle[®], Blackboard, etc.

There have been recent advances in VLEs that allow users to create, share, and reuse interactive content in the form of an open-source content collaboration framework such as Hypertext Markup Language (HTML)5 Package (H5P) (Ti-Shen and Sen 2019). This has allowed the modern VLEs to incorporate interactive videos allowing active viewing of multimedia content while answering quizzes, giving feedback on the previous content watched, etc.

Immersive Learning Environments

Immersive learning environments are a newer technology that enables the participant to explore and learn in a simulated environment or virtual world. Some examples of immersive learning environments include augmented reality and virtual reality environments. Augmented reality refers to the “augmentation” of the actual environment with 3D objects and labels, whereas virtual reality refers to the creation of a virtual environment.

Augmented reality and virtual reality environments have been used in learning and have been found to be effective in improving learning outcomes (Ferrer-Torregrosa et al. 2016; Jamali et al. 2015; Küçük et al. 2016). Augmented realities using mobile telephones to display 3D models have been used as tools for visualization in learning. Meanwhile, many mobile

applications like Augment[®] or EON[®] which can augment onto real-life environments have already been used in simulation settings.

Virtual reality environments using virtual reality headsets have also been used as tools for visualization. A detailed description of how such augmented reality and virtual reality applications can be found in a related Springer Encyclopedia (Sen and Liew 2019).

Computer-Based Assessments

Computer-based assessments refer to utilizing computer technology to assess student work. These can incorporate multiple-choice testing, parsing of language, or comparison of symbolic (mathematical) expressions. They may be diagnostic, formative, or summative. Computer-based assessments can also be integrated into virtual learning environments (e.g., Moodle quizzes) as part of the ongoing learning process for learners, allowing learners and educators alike to assess the learner's understanding.

Computer-based assessments are also increasingly being used as the medium for examinations. Many examinations have already become computer-based (e.g., Graduate Record Examination (GRE), Scholastic Aptitude Test (SAT), etc.), and some professional examinations (e.g., Associate Chartered Accountant (ACA)) have moved toward a computer-based examination.

Open-Learning Platforms

Open-learning platforms are currently in vogue in technology-enhanced learning as a means of facilitating learning. Open-learning platforms allow for sharing of learning resources through open licensing and agreements, e.g., massive open online courses (MOOCs). Some of these massive open online course initiatives include sites such as edX[®], Coursera[®], and Great Courses Plus[®].

Open-learning platforms have the benefit of being available to the general public, rather than being restricted only to the members of a particular institution. Open-learning platforms also

provide an outlet for educators in institutions to reach out to a wider audience of learners by providing tutorials and lectures to the public which, otherwise, would not have been easily available to the public.

Web 2.0 (Collaborative Technologies)

Web 2.0 refers to “the web as a platform” (Graham 2005). Web 2.0 was a development from Web 1.0, emphasizing the paradigm shift in the World Wide Web from applications to platforms (O'Reilly 2005). As a development in information technology, Web 2.0 offers community and user involvement that maps well onto many learning activities. Many technology-enhanced learning approaches that utilize the World Wide Web already use Web 2.0 as the basis for their functions.

Future Directions and Developments

The future of technology-enhanced learning moves in cadence with advances in information and related technologies. Many technologies have increased in popularity since the early days of technology-enhanced learning. The latest in the trend of technology-enhanced learning is social media technology, which has led to questions regarding their use in education (Scott 2015).

Meanwhile, the pedagogical practices behind the use of augmented and virtual reality environments as well as other educational technologies incorporated as TEL is currently an area of interest in research and there remains much to be investigated regarding their uses in education.

Incorporating most of the technologies that enhance active learning (VLE, m-learning, TELE, immersive technologies, etc.) as described in the previous sections as examples of some of the effective practices through research results, Sen and Selvaratnam (2012) designed a futuristic Technology-Enhanced Learning Laboratory – the Medical Anatomy and Pathology E-Learning (MAPEL) Laboratory – as a physical learning environment that integrates spaces, technology, and resources, with active learning pedagogies for large

student cohorts. Complex resources like digital textbooks, physical specimens and models, videos and digital image repositories, and augmented reality and virtual reality federations of specimens and body spaces were incorporated as resources within a collaborative oval table setup for multiple student groups, thus encouraging student-student, student-resources, and student-teacher interactions. These interactions were encouraged through various technology uses including a network of multi-touch tabletop computers, high-resolution projectors and multiple screens for a 360° view, document cameras, video cameras, and multicasting from BYOD teachers' tablets to screens, while the teacher is moving around groups of students. Use of the award-winning MAPEL Laboratory was found to engage students in diverse learner-resources-technology interactions and higher-order learning.

Conclusion

Technology-enhanced learning is a valuable tool in the classroom of the twenty-first century. With the development of many new technology-enhanced learning approaches, many new pedagogical concepts and practices have been developed and refined to better appropriate the advantages that technology-enhanced learning brings. With these advantages, technology-enhanced learning is poised to spearhead the learning revolution of the century.

Cross-References

- [Classroom Use, Blended Learning](#)
- [Clicker Interventions, Promoting Student Activity and Feedback at University Lectures](#)
- [Computer-Assisted Learning](#)
- [Facebook Use in Malaysian Higher Education Classroom](#)
- [Mobile Computing and Mobile Learning](#)
- [Mobile Learning](#)
- [Mobile Learning, Challenges in](#)
- [Multimodal Learning Analytics](#)
- [Rationales for Information Technology in Schools, Historical Perspective](#)
- [Smart Board Technology in Higher Education Institutions](#)
- [Tablet Use in Higher Education](#)
- [Technology Enhanced Learning](#)

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Technology-Enhanced Learning in Mathematics

► Mathematics Education and Technology

Technology-Enhanced Learning in Programming Courses, Role of

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Synonyms

Automated assessment tools; Educational programming environments; Intelligent tutoring systems; Learning management systems (LMS)

Introduction

Technology-enhanced learning (TEL) is increasingly influencing university education, mainly in overcoming disadvantages of direct instruction teaching approaches, and encouraging creativity, problem-solving, and critical thinking in student-centered, interactive learning environments. Programming is a field of studies that is accompanied with many difficulties, and TEL tools and services can improve significantly the teaching and learning of programming.

In this entry, the focus is on utilizing TEL in programming courses and more specifically on object-oriented programming (OOP) courses in higher education. The following aspects of TEL tools and services:

- Programming environments and tools
- Automated assessment tools
- Learning management systems (LMS) and tutoring systems

are examined taking into account the relevant literature and the experiences from OOP courses taught in three institutions from three different European countries. These institutions are the University of Macedonia, Thessaloniki, Greece, Department of Applied Informatics (UOM-DAI) and Department of Technology Management (UOM-TMD, since 2013 merged with UOM-DAI); University of Novi Sad, Novi Sad, Serbia, Faculty of Sciences (UNS-PMF); and University of Masaryk, Brno, Czech Republic, Faculty of Informatics (MUNI-FI). More information about the courses and a comparison between them can be found in (Ivanović et al. 2015, 2017). The three institutions have invested greatly in the advantages of TEL and their usage in delivering OOP courses. Several programming environments and systems have been developed in the three institutions for supporting the OOP courses, including the programming microworld objectKarel (Xinogalos et al. 2006), the distributed pair programming system SCEPPSYs (Tsompanoudi et al. 2016), the Svetovid system for supporting program development and assessment (Pribela et al. 2009; Pribela and Pracner 2017), a Moodle extension with personalization features, and in-house LMS. Besides these TEL environments and tools, well-known environments, such as BlueJ (Kölling et al. 2003) and Jeliot, are heavily utilized.

The rest of the entry is organized as follows. In the next section, an overview of the various types of programming environments and tools is presented, followed by research results and experiences on utilizing various programming environments and tools in teaching OOP courses. The third section presents information on automated assessment tools of programming assignments, as well as experiences from devising and utilizing such systems. The fourth section focuses on LMS and tutoring systems, types of relevant systems, typical uses of such systems in the OOP courses at the three institutions, and the results of

a survey regarding students' perceptions on the importance and utilization of TEL services (usually incorporated in LMS) especially for programming courses. Finally, some conclusions on the role of TEL in programming courses are drawn.

Programming Environments and Tools

Overview

Students learning programming face great difficulties with syntax and semantics of programming languages. These difficulties are exacerbated by the lack of support from programming environments when it comes to developing programs and understanding error messages and flow of control. In order to support students in dealing with these difficulties, different educational *programming environments and tools* have been developed and used in CS1 but also intensively in subsequent programming courses. Typically, environments of this kind aim to make the process of programming easier for students as well as to motivate them. For example (Xinogalos and Satratzemi 2004):

- *Structure editors* are used for developing programs through templates and menus and avoiding syntax errors.
- *Compilers that report user-friendly errors* are incorporated for supporting students in debugging their programs.
- *Step-by-step execution* of programs, or else *program animation*, is provided for understanding the semantics of programming constructs and flow of control.
- *Visualization* of the results of a program during execution is used for comprehending abstract programming concepts and constructs.

The main types of programming environments and tools utilized in programming courses are the following:

Programming microworlds (Brusilovsky et al. 1998) aim at using a simple language with a limited instruction set, as well as a metaphor familiar and attractive to students that is depicted on the screen. A well-known microworld

metaphor is that of a world of robots in Karel++ (Bergin et al. 1997). Programming microworlds commonly use step-by-step execution and visualization of program execution results (Xinogalos et al. 2006). A well-known OOP microworld based on Karel++ is Jeroo (Sanders and Dorn 2003). Another microworld based on Karel++ is objectKarel (Xinogalos et al. 2006) that was designed and developed at UOM-DAI. objectKarel uses a *structure editor* for guiding students through program development and avoiding syntax errors; *step-by-step execution* (program animation) with the current statement being highlighted and the robots “showing” the result in the world; *explanatory visualization* for presenting explanatory messages in natural language during the step-by-step execution of the program for supporting students that find it difficult to follow the flow of control; user-friendly and *highly informative error messages*; and a *learning module* including brief and concise theory and hands-on activities with the aim of supporting students in comprehending OOP concepts before implementing them. objectKarel has been used for several years at UOM-TMD for a brief two-lecture introduction to OOP concepts.

Educational programming environments use either an educational or a conventional programming language and aim at supporting students in dealing with difficulties through aids such as software visualization techniques, simplified user interfaces, and enhanced error reporting. The most well-known educational programming environment for OOP and Java is BlueJ (Kölling et al. 2003), which has all the aforementioned features and the possibility of direct manipulation of classes and objects. Specifically, students can experiment with existing projects: create objects by interacting with a simplified class diagram, call methods by interacting with the existing objects that are depicted in an object bench, and inspect an object’s situation during execution. The BlueJ environment has been used with positive results in all three institutions (Ivanović et al. 2015).

Algorithm and program visualization tools visualize the structure of a program or the results of its execution. Such tools can visualize either the

static or the dynamic aspects of a program (Pears et al. 2007). Jeliot (Ben-Ari et al. 2011), for example, is a code visualization tool used for supporting students in comprehending the dynamic aspects of OOP. It can be used as a plug-in for BlueJ as well. Students at UNS-PMF are encouraged to use Jeliot for code visualization.

Distributed pair programming (DPP) systems aim to achieve the advantages of pair programming (PP), but they moreover give students the chance to collaborate from anywhere and at any time. Each time one of the students has the role of the driver and writes code, and the other has the role of the navigator and monitors and comments on the code of his/her partner. Widely known advantages of PP are the exchange of knowledge, design quality, code productivity, team building and communication, and satisfaction. Several plug-ins for the widely used Java Integrated Development Environment (IDE) of Eclipse have been developed, such as Sangam, RIPPLE, XPairtise, Saros, and SCEPPSys. SCEPPSys (“Scripted Collaboration in an Educational Pair Programming System”) was designed and implemented at UOM-DAI, and it was utilized for several years for carrying out homework assignments for the compulsory OOP course (Tsompanoudi et al. 2016). SCEPPSys utilizes collaboration scripts that define the turn-taking policy, a sequence of programming tasks, and corresponding hints for guiding students.

More recently, *educational games for programming* (Malliarakis et al. 2016) have been developed for supporting students in dealing with difficulties and improving their performance. Educational games succeed in this mainly by motivating students through their immersive qualities. Several educational games for programming, such as CMX developed at UOM-DAI, have been developed, but most of them refer to younger students or imperative programming.

A well-known environment that is used for teaching OOP with Java is Greenfoot (Kölling 2010) that combines features of a programming microworld and the educational programming environment BlueJ and enhances the teaching and learning of OOP through the development of simple games.

Experiences on Utilizing Programming Environments

The Educational Technology Research Group at UOM (EdTechRG|UoM) has invested a lot of work in designing, implementing, and utilizing programming environments that promote TEL of programming. The programming microworld objectKarel and the DPP system SCEPPSYs that were designed and implemented by EdTechRG|UoM as well as the educational programming environment BlueJ were heavily utilized in OOP courses at UOM-TMD and UOM-DAI, and several studies were carried out regarding their effectiveness.

objectKarel was initially evaluated by students at UOM-DAI. Based on the results of this study (Xinogalos et al. 2006), the microworld approach to teaching programming was positively evaluated; the structure editor helped the vast majority of students in implementing their programs; step-by-step execution supported all the students in debugging and comprehending OOP concepts; and friendly error messages helped the vast majority of students in understanding and correcting the errors. Besides this pilot usage, objectKarel was used in the context of an undergraduate OO design and programming course for six consecutive years in order to introduce students to OOP concepts prior to Java at UOM-TMD. More specifically, objectKarel was used in the first two lectures of the course for helping students comprehend fundamental OOP concepts, such as objects, classes, and inheritance, prior to using Java for implementing these concepts. What is important is that the knowledge acquired in the context of the microworld was transferred afterward to Java (Xinogalos 2012). This brief introduction to OOP with objectKarel was followed by the use of the educational programming environment BlueJ. The combined use of the two environments had a positive impact on students' understanding of objects and classes and their achievements in the course (Xinogalos 2015). BlueJ, as already mentioned, was also utilized in UNS-PMF and MUNI-FI (Ivanović et al. 2015). NetBeans has recently been added as an IDE for students at MUNI-FI, while teachers still use BlueJ at lectures due to its simplicity and clarity

when using a beamer for projection. UOM-DAI utilizes mainly the Eclipse IDE.

The DPP system SCEPPSYs was utilized at UOM-DAI for carrying out homework assignments at the context of the compulsory OOP course. Based on a survey, students evaluated positively the overall experience on DPP assignments and expressed their preference in carrying out assignments collaboratively (Xinogalos et al. 2017). According to students, the benefits of DPP assignments are not just sharing of knowledge and skills, being more confident for their solution, and better code quality. Learning programming is more pleasant when DPP assignments are used, students feel more responsible being a member of a pair, and correcting syntax and logic errors becomes easier. Another study carried out in the course showed that the use of DPP improves pass rates, while the use of collaboration scripts yields equal task contributions from each member of the pair (Tsompanoudi et al. 2016).

MUNI-FI and UNS-PMF do not use any DPP system, but contemporary source code management systems, namely, Git with a local instance of Gitlab, are extensively employed to support labs in Java courses. MUNI-FI students pull source codes of their tasks from the repository and in some lab groups; they also submit their solutions this way allowing automated assessment by the lab tutors, as analyzed in section “[Automated Assessment Tools](#).” Similarly, at UNS-PMF, students submit their solutions for particular tasks this way allowing automated assessment by the lab tutors.

Automated Assessment Tools

Overview

Besides programming environments and tools, another important aspect of any programming course are programming exercises solved at labs and also assigned to students as homework. The assignment of exercises and submission of solutions, communication and collaboration during problem-solving, access to educational material, and assessment of assignments are usually accomplished with the help of LMS (Govender and

Govender 2010) and automated assessment tools (Pears et al. 2007).

Automated assessment tools automate the assessment of assignments and provide students and/or instructors with immediate feedback. Such tools can fully automate the grading of assignments, especially in cases of large numbers of students, or carry out an initial evaluation and indicate problems in students' programs (Pears et al. 2007). Moreover, automated assessment tools can check the coding style and specific design aspects of a program, as well as the usage of specific language features (Pears et al. 2007). In some cases, assessment tools provide the capability of *online submission* as well, as is the case with BOSS and Web-CAT (Rößling et al. 2008).

Experiences on Utilizing Automated Assessment Tools

Homework assignments at UOM-TMD in the past and UOM-DAI currently are corrected manually by the instructors. However, in the case of DPP assignments, SCEPPSYs records information during problem-solving and reports various statistics that provide a form of an initial evaluation and can indicate problems in students' programs. Statistics are reported for each pair of students and for the whole class (mean value) as well: total time spent to solve a project (min), driving time spent to solve a project (min), number of project runs, number of role switches, number of retrieved hints, contribution of each student (number of characters), contribution of each student (in %), number of steps solved according to role distribution policy, and messages sent by each student through the incorporated chat tool. Although the instructors have to manually assess the assignments, the aforementioned statistics can assist in (Xinogalos et al. 2016) detecting difficulties with specific OOP concepts/constructs, detecting students' progress in programming, detecting undesirable behaviors (e.g., plagiarism), and detecting problems in collaboration between the members of a pair.

UNS-PMF has been using for more than 10 years the in-house assessment tool Svetovid, which is an interactive development environment integrated with a secure submission system for students' lab and/or homework solutions. The

initial version of the system represented the first layer of defense preventing students' cheating. In the meanwhile, the system has been evolving, and the use of ubiquitous social media platforms influenced the implementation of a second layer of defense. This second layer represents detection and investigation of any wrongdoing and is enabled by tracking of history and evolution of the student's solution through time. To address this and the other problems, Svetovid implemented a special file system where Git was adopted (Pribela and Pracner 2017). Such innovation has some advantages. This means that not only the final submitted version is stored and the student could restore an older version of the assignment that was possibly more correct. The teacher can also have a better understanding of the development process of the solution and can evaluate its evolution and not only the final state.

MUNI-FI uses a semiautomated system for assessment of students' homework. They either submit their solutions using the in-house developed information system of MUNI or push their solutions to Gitlab. In both cases, their submissions are subject to semiautomated process when the tutors run the unit tests provided (and known to students prior to submission). In addition, students are forced to follow the Java coding conventions by Checkstyle. A different regime applies to in-class tests where the students have limited time to deliver a working program as their solution; the program must compile and produce the desired result which is, however, tested manually.

Learning Management Systems

Overview

The utilization of an LMS in a programming course is considered important. Past research found that students' satisfaction with TEL services tends to be positively correlated with different factors such as:

- Course content and quality (Naveh et al. 2010; Selim 2007; Sun et al. 2008).
- Instructors' attitudes toward technology-enhanced learning and students' technical competency (Selim 2007; Sun et al. 2008).

- Diversity in assessments (Sun et al. 2008).
- The existence of bulletin boards and discussion forums (Basioudis et al. 2012).
- Efficient transmission of course materials and announcements (Lonn and Teasley 2009).
- Actual use and students' involvement (Klobas and McGill 2010).

The study by Emelyanova and Voronina (2014) indicated that there is a remarkable divergence of students' and teachers' perceptions of LMS regarding their usefulness, appropriateness, and interest for the students. In a recent literature review of students' usage of LMS, Lust et al. (2012) showed that students generally perceive LMS as useful and easy to use.

LMS in general are heavily used for enhancing the learning experience of students by providing them access to educational material, improving communication and collaboration, and aiding in testing of the acquired knowledge. In the case of programming courses, students expect to receive even more enhanced support from the LMS, such as support in problem-solving (Govender and Govender 2010). As mentioned in the report of the ITiCSE 2008 "Working Group on Design Patterns for Online Learning Environments in Computer Science," the features of a typical LMS do not meet certain needs of Computer Science Education (Röbbling et al. 2008). For this purpose, an LMS that is extended specifically for CSE is proposed and referred to as *Computing Augmented Learning Management System* (CALMS) (Röbbling et al. 2008). Thota and Whitfield (2009), for example, report on the ongoing development of a CALMS based on Moodle for an introductory programming course, which they envision to enrich with facilities for automatic assessment and plagiarism detection, automatic feedback for programming assignments, and peer evaluation of programming assignments.

Experiences on Using LMS and Tutoring Systems

At UNS-PMF, students can use Moodle with extended personalization features (Komlenov et al. 2010; Verpoorten et al. 2009) or the in-house developed intelligent tutoring system Protus. Protus is a multifunctional e-learning environment

for supporting intelligent tutoring and some elements of personal and pedagogical assistance agents (Ivanović et al. 2018). The OOP course within Moodle consists of teaching materials and a mix of synchronous/asynchronous activities and resources. The e-lessons are used as asynchronous activities, such as quizzes, glossaries, wikis, and discussion forums. In addition, live discussions occur regularly; some of the resources used during lab exercises and assignments are formulated and graded online and then solved individually during regular classes. On the other hand, Protus has been designed to support students with personalized courses that include teaching material but also elements for testing of acquired knowledge. Protus has been increasing the learning opportunities, challenges, and efficiency supporting adaptive learning based on learning styles and recommender systems. Protus also supports scaffolding teaching that helps students to understand better and adopt difficult OO programming concepts.

Such assistance can help the students in different ways: suggest them to take the most suitable learning actions, monitor students' progress, track students' cognitive learning styles, and offer highly learner-adaptive environment.

At UOM-TMD, UOM-DAI, and MUNI-FI, an in-house LMS is used, which is however used for all courses at the corresponding institutions. The LMS used in the three institutions have all an integrated discussion forum and an email system that are heavily used for communication and collaboration. Typical usage scenarios of LMS services are presented in Table 1.

Students' Perceptions on the Utilization of TEL Services Provided in LMS

To the best of the authors' knowledge, there are only two comprehensive studies providing an international comparative analysis of students' perception of learning management systems and accompanying TEL features and services (Basioudis et al. 2012; Ivanović et al. 2017). The study by Basioudis et al. (2012) investigated how undergraduate accounting students from the UK, Australia, and New Zealand perceive the importance of generic TEL features present in LMSs. The main conclusion of the analysis is that student satisfaction with the use of an LMS is strongly

Technology-Enhanced Learning in Programming Courses, Role of, Table 1 Typical usage of LMS in programming courses

	Course's description	Calendar	Documents	Students' assignments	Discussion forum	Announcements
<i>Course organization and management</i>	Provides important info that plays the role of a didactical contract between students and the instructor	History of lectures/labs	The structure of folders depicts the organization of lectures/labs. Folders and files can be easily (de) activated during the preparation of a unit	Assignment of weekly homework is realized exclusively through the system, saving class time. Students' solutions can be downloaded organized in folder		Announcements regarding important scheduled (i.e., lectures/labs, exams) and unscheduled events (i.e., changes in program) can be posted and sent by email to enrolled students
<i>Student guidance</i>	Information regarding the general didactical aims, course content, textbooks, software, learning design, and grading policy guide students through the course	Provides information for the content and the material of each lecture/lab carried out and where it can be found in the system	Students know that the last visible folder represents the most recent lecture	Students have available the necessary homework material and submission deadlines		Students are guided by the instructor through the semester for all important events
<i>Enhanced learning</i>	All the necessary course information is available online, which reduces students' anxiety and supports them in planning their learning	Provides information for catching up with missed lectures/labs	Availability of PP slides and the material used at lectures allows students to concentrate on understanding what is presented and not just keeping notes, while the material is error-free. Material is available from anywhere	Easy online submission of assignments at any time and as many times as wanted (within the deadline) from anywhere, as well as ability to submit part of the assignments, motivates students to do their homework, which is essential for learning programming	Through many to many communication	

(continued)

Technology-Enhanced Learning in Programming Courses, Role of, Table 1 (continued)

	Course's description	Calendar	Documents	Students' assignments	Discussion forum	Announcements
<i>Communication and collaboration</i>					Students can ask for help regarding queries on theory, assignments, and so on and get feedback from colleagues and the instructor	
<i>Support in problem-solving</i>			Supplementary material, such as commented programs, can be provided for supporting students in problem-solving	Guidelines and hints can be added at any time in the "assignments area" based on students' questions, helping students get unstuck and finish their assignments	Students are encouraged to use the forum for getting help from colleagues and the instructor during problem-solving (homework)	Announcements are made for supporting students in problem-solving in the case that the instructor finds out that homework has any unclear specifications or it is too challenging for students

influenced by the availability of lecture notes and the utilization of online assessment, announcements, model answers, and online chat features.

In one of the authors' previous studies (Ivanović et al. 2017), a survey was carried out in order to analyze students' perception and actual utilization of TEL services supporting the teaching of object-oriented programming courses at three institutions. The analysis included not only TEL services currently used within OOP courses but also TEL services planned to be used in the future. The most important information for this study is given in Table 2.

The analysis of collected questionnaire responses revealed that students perceive the usage of LMS and Moodle for the distribution of didactical material and the organization of assignments as very important or absolutely essential. Announcements and automatic notifications enabled by LMS/Moodle are also considered as very useful. Although considered as important TEL services, LMS/Moodle forums tend to be rarely used by students. As the main reasons for not posting on forums, students indicated that (1) they did not need

LMS forums to communicate with teachers and colleagues and (2) they did not want other enrolled students see their questions. A similar situation was observed regarding the usage of instant messaging (IM) tools to communicate with instructors: students prefer more to use e-mail or to approach instructors personally rather to use IM tools.

The second part of the questionnaire asked respondents to evaluate the importance of features that could be offered by TEL tools. Students evaluated supplementary education material and exemplary solved problems given on LMS as highly important, while online self-evaluation quizzes, the adaptability of e-lessons, and tracking learning style are considered as important TEL services.

Nonparametric statistical test revealed a high similarity between UNS-PMF and MUNI-FI students with respect to the perceived importance of TEL services. On the other hand, students from UOM-TMD gave significantly higher ratings to the use of CMS for assignments and the distribution of didactical material, the adaptability of e-lessons, and tracking learning style LMS features. The observed difference can be explained by the nature

Technology-Enhanced Learning in Programming Courses, Role of, Table 2 Information for the study investigating students' perception and actual utilization of TEL services used in teaching object-oriented programming

Participants	93 students from the University of Macedonia (UOM-TMD), Greece 80 students from Masaryk University, Czech Republic 113 students from the University of Novi Sad, Serbia 286 students in total
Questionnaire	13 questions separated in two parts <i>Questions of the first part:</i> importance and utilization of TEL services used for teaching object-oriented programming at the authors' three institutions (the organization and distribution of teaching material, assignment services, communication, and cooperation services) <i>Questions of the second part:</i> perceived usefulness of TEL services planned to be used in the near future (online self-evaluation quizzes, supplementary educational material and exemplary solved problems in electronic forms, and adaptability of e-lessons according to learning styles) <i>Five-point Likert scale was used:</i> not at all (1); slightly (2); averagely (3); much (4); very much (5).
Statistical analysis	The internal consistency of collected questionnaire responses was assessed using Cronbach's alpha coefficient Median and mode were used to determine central tendencies in students' responses to questionnaire items. The interquartile range was employed to measure variability in responses Nonparametric statistical tests (Kruskal-Wallis ANOVA, Mann-Whitney U, and two sample Kolmogorov-Smirnov tests) and probabilities of superiority were used to compare questionnaire responses of two or more independent groups of students determined by various criteria (institution, year of study, the average grade)

of the UOM-TMD computer science study program which is more oriented toward technology management compared to computer science study programs at UNS-PMF and MUNI-FI. The statistical analysis also revealed that the perception of the importance of TEL services does not tend to be significantly associated with study year and students' average grade.

Conclusions

TEL can play an important role in the teaching and learning of programming, no matter what the programming technique and language are. This entry focuses on OOP courses, but the results apply in any programming course since the TEL services analyzed are independent of the programming techniques, while similar TEL tools examined for OOP exist for other programming techniques as well.

An important aspect of an OOP course is the programming environments and tools utilized in labs and assignments for practicing programming. A wide list of environments is available for OOP that cover the different needs of students. For example, programming microworlds can be utilized for introducing non-computer science (CS) majors to OOP concepts smoothly. Educational programming environments utilizing Java, such

as BlueJ, can be used in any case. DPP programming systems based on the professional Java Integrated Development Environment Eclipse can be utilized by CS students for carrying out homework assignments, while code visualization tools can be used for comprehending the dynamic aspects of object-oriented programs.

Another important aspect of a programming course is providing immediate and accurate feedback on students for their programming assignments. In case of big numbers of students attending a course, this can be actually accomplished only by utilizing automated assessment tools. Tools that record information during problem-solving and calculate and report various statistics can also help instructors monitor the achievement of the didactical goals of their courses.

Finally, an important aspect of any programming course is orchestrating and managing lectures, labs, announcement and submission of homework assignments and projects, delivery of educational material, providing support during problem-solving, and communication with and between students. All these can be accomplished through a typical LMS or even better with an LMS enhanced with services specifically for delivering programming courses. Based on a survey carried out in the authors' institutions, but also in previous studies, it came out that students perceive the

usage of TEL tools for organization and distribution of teaching material, assignment activities, and announcements as either very important or absolutely essential. Forums provided by TEL tools are also considered very important, although they are not extensively utilized especially in cases where the students have the choice of face-to-face communication with instructors. The survey also indicated that students show very high interest in exemplary problem solutions and supplementary educational material in the form of e-lessons, as well as personalization features.

Concluding, existing TEL tools and services can enhance the teaching and learning of programming courses. Several possibilities for even more elaborated TEL tools and services for programming courses exist that require further work in the field.

Cross-References

- ▶ [Digital Technologies in Higher Education, Learning Challenges](#)
- ▶ [First Programming Language in Introductory Programming Courses, Role of](#)
- ▶ [Learning Behaviors in Programming](#)
- ▶ [Learning Management Systems, An Overview](#)
- ▶ [Learning Programming, Student Motivation](#)
- ▶ [Learning Programming, Success Factors](#)
- ▶ [Teaching Computer Languages in Universities](#)
- ▶ [Technology Enhanced learning](#)

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Ultranet

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Synonyms

[Extranet](#); [Internet](#); [Intranet](#)

Introduction

Parents of schoolchildren want to be well informed and know as much as possible about their children's school and how their children are progressing at school. In 2010 the State Government of Victoria, Australia, launched an online system, the Ultranet, for connecting and

informing school communities using web-based technology. The Ultranet was launched in 2010 and, after a short life, finally abandoned in June 2013. This entry addresses the socio-technical nature of the Ultranet, its development, and the possibilities it offered and examines why they did not fully eventuate.

The Ultranet was intended to support knowledge sharing across Victorian Government Schools and to be used by over 540,000 students and their parents in 1,555 government schools along with their 40,000 teachers (Australian Bureau of Statistics 2010; DEECD 2010b). It was intended to provide facilities for keeping parents informed about their children's schooling as well as for curriculum delivery and online teaching and learning. Traditionally, parents were kept informed about their child's progress at school through the use of printed school reports, parent-teacher evenings, and an annual "Open Day." Reporting in some form is important as parents all want to know as much as possible about the school where their children spend so much time and also how well they are progressing (Davey and Tatnall 2012). At this point the Ultranet entered the scene (Fig. 1).

Ultranet Background

Altgh many education systems around the world have made use of tools like those found in learning management systems such as Blackboard



Ultranet, Fig. 1 What is the Ultranet? (DEECD 2011b)

and Moodle for online teaching and learning, the Ultranet was quite different in that it was designed to also provide information to parents.

The Ultranet was designed for three principle uses (Tatnall and Dakich 2011):

- To allow student access to personalized learning activities and keep an ongoing record
- To allow teachers to create curriculum plans, collaborate with other teachers, monitor student progress, and manage student assessment
- To allow parents to view information to help them keep up to date with their child's learning.

The Ultranet had many of the features of a business extranet in that it was closed to people outside the Victorian Government School community and required a username and password to gain access (Davey and Tatnall 2013) (An **extranet** is a private network (based on web technologies) that links selected parts of

an organization's intranet with its customers, suppliers, and other authorized business partners.).

The Ultranet was based on the use of what it called Spaces, each of which was intended to allow different information to be accessed and different learning activities to be performed (Tatnall 2011). Each Space was classified by its accessibility into one of the following categories:

- **Me Spaces** were private spaces accessible only by the owner.
- **We Spaces** were shared spaces seen by those with permission to be in that space.
- **See Spaces** were public, open-access spaces that could be seen by the whole world.

These spaces were:

1. **Home** – a personalized page for students, parents, and teachers to see school or community

- notices and where students and teachers could add their favorite applications (a Me Space).
2. **eXpress Space** – a personal We Space for students and teachers to capture, share, and reflect on their learning.
 3. **Design** – a Me Space for teachers (only) to plan, create, and collaborate with colleagues within and across schools and design curriculum and student learning activities.
 4. **Community** – a space where students, parents, and teachers could find school news and events and be involved in school-based groups, clubs, or activities (a We Space).
 5. **Collaborative Learning** – where students could take part in online learning activities set up by their teachers (a We Space).
 6. **Learner Profile** – a We Space where students, their parents, and teachers could view a detailed profile of students' individual learning progress.
 7. **Learning Tasks** – a We Space for teachers to plan, deliver, and assess learning activities and for students to view and submit learning tasks.
 8. **My Content** – a space where teachers and students could store and search for personal, school, and quality-assured digital learning resources (a We Space).
 9. **Connect** – allowed students to find reviewed websites and online activities (Fig. 2).

The Ultranet's underlying technology was based mainly on Oracle and incorporated various Web 2.0 technologies. The Ultranet was thus intended to be a closed, secure place on the Internet, accessible by students, teachers, and parents from the school community.

The Department of Education and Early Childhood Development (DEECD)'s 2010 website noted that, specifically, the Ultranet was designed to:

- Enable parents to become full partners in their child's education, giving them online access to their child's homework, attendance, assessment, curriculum and teacher feedback at any time.
- Ensure that every child will have a complete record of achievement across all years of schooling.

- Give students their own online workspaces, personally tailored education programs, direct feedback from teachers and better access to curriculum.
- Enable students in remote schools to access specialised curriculum and podcast classes from schools that excel in various subject areas.
- Allow students to learn in an environment that will ensure that they have the cutting edge ICT skills they will need in the 21st century workforce.
- Reduce the administrative burden for teachers and schools by using the Ultranet for recording attendance, school reports, timetabling and school events, to pool schools' resources and give teachers access to a vast central database of classroom resources. (DEECD 2010a)

A major goal of the Ultranet Project was to improve communication between the school and its teachers with parents. In 2012, the Education Department's website announced that:

As a parent, the Ultranet will give you more detailed and timely access to information so you can monitor and support your child's learning. Information about your child and their school will build over time as schools progressively implement and use the Ultranet's many functions. In just a few clicks, you will be able to see your child's latest: attendance records, learning progress information, teacher feedback, in-class or at-home tasks and timetable. (DEECD 2012)

Development and Use of the Ultranet

In the mid-1990s Victoria set up a number of "Navigator Schools" whose purpose was to develop the use of ICT to improve both teaching and learning and school administration. In the early 2000s, Glen Waverley Secondary College, as a Navigator School, in a joint venture with Impaq Educational Services developed an effective school intranet that transformed the way the students and staff gained access to each other and to curriculum resources (Toomey et al. 2000). The Education Department was impressed that Glen Waverley Secondary College had provided: "an intuitive interface that seamlessly brings together various aspects of classroom 'business' (teaching and learning plus other associated administrative functions) into a single, central, logical environment that has a profound



Ultrahet, Fig. 2 “Spaces” on the Ultrahet (DEECD 2010a)

impact upon the way teachers, students, parents and other key staff share information and cooperate” (EduWeb 2006).

In 2005 the Ultrahet concept began to take life when the Education Department, building on the Glen Waverley Secondary College concept, commenced a joint R&D initiative with Oracle Corporation to produce “the prototype for a student centric system that supports teaching and learning, curriculum delivery and the management of knowledge in Victorian schools” (DEECD 2005). The prototype was to be

known as the Ultrahet and be based on Oracle technology. In 2006 to test the feasibility of these ideas, a “proof of concept” system was developed by the University of Melbourne and trialled in 22 schools over 18 months (Griffin and Woods 2006; Tatnall et al. 2013). The trial aimed to establish whether such a project was viable, to determine functional requirements, to identify any possible user and technical issues, and to investigate development and implementation costs. It was reported as a “proof of concept student-centric ICT system, called

Students@Centre, to support online teaching and learning, curriculum delivery and knowledge management in Victorian government schools” (DEECD 2010c). In 2006 the Victorian Government made an election commitment for \$60 million to build the Ultrahet (EduWeb 2006; Tatnall et al. 2013) and have it operational before the 2010 election.

The Ultrahet was launched in August 2010 when Victoria’s 1,500 State Schools were closed for an extraordinary student-free day for teacher professional development (DEECD 2010d). All 3,500 State School Principals and Assistant Principals were called to Melbourne to attend Ultrahet’s “Big Day Out” at the Melbourne Exhibition and Convention Centre to learn about the state’s new online learning network. Teachers across the state were asked to familiarize themselves with the Ultrahet from their own school location, but unfortunately the launch turned into a fiasco when the Ultrahet crashed disastrously at 9 am (Tatnall et al. 2013). Later when the system was running again, many teachers and principals experienced problems when they attempted to log on and reported it as running extremely slowly (Holden 2010; Levy 2010; Topsfield 2010).

Each Education Department Region appointed a number of “Ultrahet Coaches,” who were given 6 days of professional training and then based at a school. Their task was to service a small group of local schools with the goal of supporting teachers to prepare for the Ultrahet and to build ICT capacity in the classroom (DEECD 2009). As well as these coaches, each school was asked to appoint an “Ultrahet Champion” known as a “Lead User” who was provided with 2 days of professional training by the local Ultrahet Coach and given support materials and whose role was to offer ideas for school-based professional learning strategies and to promote use of the Ultrahet.

By 2012 the Ultrahet was well used by certain schools, centered mainly on a couple of country regions, both as a tool for student collaboration and as a means of communicating with parents. It had, however, not achieved the expected benefits for students, parents, and schools around the State, had a very low uptake by users, and had

not achieved the functionality originally intended (Victorian Auditor-General’s Office 2012).

DEECD has not fully considered the demand the Ultrahet would have on teachers’ time and workload, particularly in terms of teachers’ roles in supporting and guiding parents on how to use the Ultrahet . . . System problems have also discouraged uptake . . . These include the Ultrahet’s technical unreliability and poor performance, the lack of appropriate support to develop Principals’ and Teachers’ ICT competency and confidence, and ageing ICT infrastructure and devices (which can affect online access to the Ultrahet). (Victorian Auditor-General’s Office 2012: 30)

The original budget for building the Ultrahet was \$60 million, but this later turned out to be a very optimistic underestimate, increasing to three times this (\$180 million) before completion (Sharp 2013). DEECD claimed that an early evaluation pointed to positive teacher attitudes in the use of such an online environment but after that the adoption and use of the Ultrahet was much less than expected. Although it seemed like a good idea at the time with lots of possibilities to do worthwhile things, by late 2012 it was not being used to any great extent in most schools and was abandoned by the Government in June 2013 when DEECD signed an agreement with NEC that would come into operation in January 2014. The agreement was for NEC to continue provision of the Ultrahet, but only to schools that were prepared to use the service on an individual user-pays basis (Sharp 2013).

The Ultrahet and Technological Innovation

Any investigation of the adoption and failure of the Ultrahet must consider both its technical and its human components, and so this must necessarily involve a socio-technical research approach and methods. It is useful to consider the Ultrahet project as an example of technological innovation and to view it through the lens of technology adoption. Actor-Network Theory (ANT), or the “sociology of translations” (Callon 1986; Latour 1988, 1996; Law 1992), was designed to deal with socio-technical research in a way that would

address the need to treat the contributions of both human and nonhuman actors fairly and in the same way and was developed to analyze situations where separation of human and nonhuman elements is difficult (Latour 1993; Callon 1999; Tatnall and Gilding 1999; Tatnall 2000, 2009). It was clear from the beginning that the failure of the Ultrahet was not due to technology alone, and so ANT, and in particular Innovation Translation (Callon 1986), was used as a lens to understand why the Ultrahet was not adopted to the extent intended.

Innovation Translation sees the process of innovation in terms of translation (adaptation) from one state to another. Callon (1986) suggests that the process of translation has four aspects or “moments”: problematization, intersement, enrollment, and mobilization.

- Problematization involves one or more key actors that attempt to define the nature of the problems so as to be seen by other actors as having the answer (McMaster et al. 1997).
- Intersement involves interesting and attracting an entity by coming between it and some other opposing entity (Grint and Woolgar 1997).
- Enrollment occurs through a process of “coercion, seduction, or consent” (Grint and Woolgar 1997), and if all goes well, it leads to the establishment of a solid, stable network of alliances.
- Mobilization locks in as the solution proposed gains wider acceptance through some actors working to convince others (McMaster et al. 1997).

Failure of the Ultrahet

The problematization of the Ultrahet by the Government as a system to offer access to learning materials and to inform parents of their child’s progress seemed worthwhile to many when it was first proposed. What should have happened next was that considerable effort should have been put into convincing teachers and parents to accept this problematization and so

become enrolled. This, however, did not happen – there was a major failure of intersement!

An innovation is of little value unless it is adopted, and it will only be adopted if it can be adapted in such a way as to fill a need, that is unless it can be translated. In this case the Ultrahet failed to establish such a need. The problematization of the Ultrahet as “a student-centred electronic learning environment that supports high quality learning and teaching, connects students, teachers and parents and enables efficient knowledge transfer” (DEECD 2011a) was generally accepted, but teachers, however, were not entirely happy with all aspects of it connecting with parents and some saw this as a threat.

The first attempt to convince teachers of the value of the Ultrahet was at the “Big Day Out” and student-free day for professional development. This attempted intersement was a disaster that, far from convincing teachers of the Ultrahet’s worth, did exactly the opposite. Another attempt at intersement was the appointment of Ultrahet Coaches, but, in an informal conversation, one primary school principal indicated that the Ultrahet Coach who had visited them did not seem to understand the human issues involved in convincing teachers and parents to use the Ultrahet. The Coach was of the view that as DEECD had decreed that it be used, that was the end of it (Tatnall et al. 2011). This primary school had decided not to introduce the Ultrahet to parents until such time as there was something worthwhile on it for them to see – until it had some data about their own children. The Coach did not seem to understand this. In another failure of intersement, a parent of secondary schoolchildren pointed out that he had not been able to find out much about the Ultrahet and that as far as he was aware his children’s school was not using it. Clearly there should have been a good deal more done to convince principals, teachers, and parents of the Ultrahet’s value. The human aspect of promoting the Ultrahet was not given sufficient consideration.

The possibilities offered by the Victorian Education Ultrahet were considerable, but its uptake by schools was not. The solutions offered by the Ultrahet had value, but they were not

solutions to any existing problems that had been identified by schools or by teachers.

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Underrepresentation of Girls in Computing

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Synonyms

Girls in IT

Background

For many decades, females have been underrepresented in both the studying of computing and computing careers (Hoyle 1988; Varma 2010). As early as primary school, both male and female students are exposed to computing and are encouraged to use computers within their classrooms; however, as students progress to secondary school, gender inequality increases with age, and female students tend to not engage with undertaking computing classes (Larsen 2010). This is not country specific, but rather seen as a pattern in many countries including Australia, the United States, and the United Kingdom. By the time female students enter their final years of formal secondary education, the gender gap in the study of computing has widened deeply (Kirkpatrick and Cuban 1998).

At primary school level, students do not select subjects; rather they are exposed to a variety of

experiences and challenges. However, in secondary school and especially in the final years of schooling, students can elect the subjects they wish to study. The age of disparity has been identified at approximately 12 years of age, where there are gender imbalances in mathematics, science, and technology (Sáinz and Eccles 2012). The situation is more apparent as students enter their final years of secondary school and then university (Zagami et al. 2015). Typically, it is reported that the percentage of female computing students is approximately 20% (Falkner et al. 2015). These numbers are not high and raise concerns that are shared among teachers, academics, and computer professionals about the lack of female participation in computing subjects at both secondary school and tertiary level.

Globally

Computing is not a commonly sought-after career for young women. The problem is not confined or isolated to one continent, but on a global level; it is widespread across many continents – North America, Europe, and Australia (Deloitte 2016; Deloitte Access Economics 2016). The number of females graduating with a computing degree has consistently declined since the 1980s and now accounts for less than 18% of computing graduates (Hutchinson and Tadros 2014; NCWIT 2014). Typically, there are five times more men than women studying computing at tertiary level. These figures are replicated in the information technology (IT) industry where women currently constitute a small part of the workforce – 24% in the United States, 18% in the United Kingdom (UK), and 28% in Australia (Deloitte 2016; Deloitte Access Economics 2016).

Lack of gender diversity in this industry has implications for both society and organizations. There is increasing evidence that gender diversity in organizations has a positive influence on productivity such as higher sales revenues, more customers, and greater profitability (Herring 2009). However, the lack of gender diversity is due to the fact that it is very difficult to recruit capable and confident people with IT skills, particularly as the talent pool is restricted by the lack of qualified

women. Encouraging more women into university computing courses would lead to an increase in both the size and diversity of a country's skilled workforce and address the growing shortfall of computing professionals in industry.

Social Conditioning

Sociological factors are very important when explaining the gender differences in computing participation. From the early 1980s, computing has been seen as a subject that promotes isolation, abstract concepts, and activities reflecting masculine interests. Careers in computing have been seen as a masculine career that is associated with a high level of mathematical competence, low levels of social skills, and individual working conditions (Ensmenger 2015; von Hellens and Nielsen 2001). When this is combined with the absence of female role models and mentors, it is hardly surprising that females do not choose these fields of study.

Female attitudes to careers and work are shaped by family, friends, school, and more broadly society (Trauth et al. 2004). Family is the most powerful of influences. It has been widely acknowledged that parents (including guardians) encourage their sons to take computer classes and excel in this field of study; however, conversely, this is not the case with daughters. Historically, computers, computer games, and programming have been culturally perceived as a male enterprise (Klawe 2002; Willoughby 2008).

Female perceptions are molded by people close to them such as their mothers (Stockdale and Keane 2016). It has been known that mothers have shared horror stories they had in mathematics and science classes and negative issues they had with workplace computers. These stories tend to shape the attitudes of girls and thus the informal stereotyping that takes place within our society (Fiebig and Beauregard 2011). Female students are influenced by many people who are close to them, and this influence, whether it is positive or negative, impacts on their decisions to study computing. A mother's deep-seated gender-role opinions can have significant influence on the selection of their daughter's career choice (Bleeker and Jacobs 2004).

Careers in Computing

In addition to the influence of family and society, young females generally have a negative attitude to working in computing careers. Female students have little, if any, knowledge of the computing industry and the career opportunities within the industry. In fact, the computing industries themselves find it hard to describe what careers in computing actually are. Unlike other careers, such as teaching or medicine, whereby graduates become teachers or doctors, a career in computing is very difficult to describe and identify the likely vocation. Most people generally can identify one career in computing (such as computer programmers), and while there are many others, these are not well promoted or advertised. To further complicate this, there is an ongoing shift in the field, and the emergence of new or unknown jobs is being created which make it hard to keep up. This also contributes to the unattractiveness of the computing industry (Clayton et al. 2009).

Computer Games

From an early age, children are exposed to various forms of entertainment such as computer applications on tablet devices and electronic games such as Nintendo, PlayStation, and Xbox. Typically, games have always been more appealing to boys than to girls (Tomte 2008). Predictably, boys play video games far more than girls do. Some schools have promoted computer use through computer games which tends to be more attractive to boys than girls due to the competitive nature of the content (Willoughby 2008). However, other reasons have been attributed to the fantasy-based pretend play that attracts boys to gaming and girls' preference to reality-based pretend play.

Public Face of Computing

The world of computing seems to be almost exclusively male, spanning from the early humble beginnings to where we are today. Its public face is dominantly male; they are developers of computers, computer software, and social media.

For example, Bill Gates and Paul Allen from Microsoft; Steve Jobs and Steve Wozniak from Apple computers; H. Edwards Roberts from Altair 880; Mark Zuckerberg from Facebook; Jack Dorsey, Noah Glass, Biz Stone, and Evan Williams from Twitter; and Kevin Systrom and Mike Krieger from Instagram are all male. Many of these men are seen as visionaries, forward thinkers, and leaders. The dominance of male leadership in this context can be seen to reinforce a notion that this is not an area of activity where females are likely to find leadership.

Computers and Popular Culture

Computers have been portrayed through film, television, and literature since the late 1960s, such as 2001: *A Space Odyssey*. Typical portrayal of computers on film, literature, or television often shows males in positions of expertise or heroism, such as in the film *War Games* (1983). The simple premise of the movie is that the girl in the movie knows nothing of computers. At the end of the film, it is up to the boy and the programmer to stop a computer from blowing up the world. At the climax of the film, the simple logic of tic-tac-toes stops the computer from initiating nuclear Armageddon. The film portrays the kind of logical thought necessary to program and understand computers as being the exclusive province of men. Right from the outset, computer expertise in such popular entertainment is linked with males, not females.

Another example is Michael Crichton's book *Disclosure* (a movie was also made of this in 1994), where Crichton puts women in positions of great power in a Californian computer company; however, those with the expertise in computers are the men. Keeping in mind that this is a book with strong women roles, the two significant women are not shown as having computer expertise, that is, in this case, not possessing the technical aspects of computing in comparison to the male colleague who is made to appear that he is expert in all that is computing.

More disturbing than these examples, though, are portrayals in popular literature of women

using computers. These are more disturbing because invariably the female use of computers is portrayed as a woman's means of using a computer as a substitute for real life. In the *Batman Comic* series, Commissioner Gordon's niece Barbara turns to computers and adopts the identity of Oracle after she is crippled following a frenzied attack by a super-villain. Likewise, in the film *Copycat* (1995), Sigourney Weaver's character communicates through computers after being so traumatized following an attack by a psychopathic killer, that she is unable to venture outside. Similarly, Sandra Bullock's character in the film *The Net* (1995) is shown to have no other life than the one she works on with her computer. Working from home, with no friends, nobody knows who she is; she has no outside interest, no relationship, and no life. Even though at the end of the film she wins the day through her computer expertise, she still does not end up with very much in her life.

A further example comes from the television sitcom, *The IT Crowd*, which is set in an Information Technology Office in a large fictional British corporation. The show focuses on three members of the IT support team whose office is in a basement that is disorderly and shabby. Stereotypically, the two technicians do not have well-developed social skills and are not held highly by other people in the organization. While it is a parody, it reinforces the characteristics and attributes of people drawn to the computing profession.

Summary

The underrepresentation of girls in computing has been an ongoing problem for many decades. While there have been many studies examining why girls do not elect to study computing, a solution to this problem has not been found. There are many theories as to why girls do not study computing or chose not to enter the profession, such as the subject matter is not appealing or the industry is unattractive. The lack of strong female leadership as visionaries sends a strong message to young girls that computing is

not a domain for them. The popular media also reinforce this message through film and television by not having strong female leads who can competently use computers. Alternatively, other portrayals include satirizing attributes of people who are drawn to the profession such as those who lack social skills or prefer to work in isolation. While there is no clear solution, there are many stakeholders who are trying to address this issue, from curriculum writers in schools, to universities, to companies that are offering programs specifically targeted at girls, and to employers who are trying to make the industry enticing. While no specific program or stakeholder has been able to redress the underrepresentation of females in computing, much work and research have been conducted to understand the issues which have contributed to this problem (Butler 2000).

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Using Social Media to Promote Academic Functioning

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Social media has been used by organizations to sell products, to mobilize people politically, to share information, and to connect individuals with each other. Given the ubiquity of social media in our society, it is not unsurprising that academic departments and universities have turned to social media as a tool to connect with students, alumni, faculty, and other constituent groups.

Social Media Platforms

Different platforms have been used by universities. Facebook with its groups and pages functions has been more popular (e.g., Lawson et al. 2011; Zickar et al. 2018). Facebook groups and pages have been used to communicate with alumni (Farrow and Yuan 2011); to communicate information to students, alumni, and other constituent groups (Zickar et al. 2018); and to disseminate advice to first-year college students to help in their transitions (Russell et al. 2012).

Twitter and LinkedIn have been used by academics to develop networking opportunities (Donelan 2016) and to disseminate research to fellow researchers and to media (Mas-Bleda et al. 2014). Finally, academics have used a variety of social media platforms to teach additional content to college students (see Wankel 2010). Additional platforms such as Instagram and Snapchat are currently popular with undergraduate students, though there has been little research on how universities and faculty can use these tools to connect with students.

In addition to promoting academic functioning, social media can be used to help advertise academic programs and universities. Detailed metrics collected by social media companies can be used to advertise programs to targeted applicants. For example, using Facebook advertising, one could market a graduate degree in psychology to individuals in a particular geographic region who are within a specific age range who already have a bachelor's degree and express interest in psychology.

Individual researchers can use social media to make sure their research articles reach a larger audience than would be expected to read traditional academic scholarship. There are some academics who have built large followings on platforms such as Twitter, though research suggests that social media followings should not supplant traditional academic metrics for influence (Stewart 2015). These platforms, though, can help spread the impact of scholarly research and can help connect researchers who share similar interests.

Challenges Using Social Media to Promote Academic Functioning

Using social media to connect with students and other audiences has many challenges. First, user preferences change for various platform changes over time, and so it requires faculty and administrators to regularly learn new tools and platforms and to be sensitive to demographic-based preferences. In addition, social media platforms change their functioning on a regular basis, and it can take a lot of effort to keep on top of these technological changes. It is important that the person (or persons) who run a particular social media outlet receives periodic training on best practices, as those best practices change frequently.

In addition, to use social media effectively, new content must be posted on a regular basis. Finding and curating content can be a time-consuming chore for overwhelmed academics. In many cases, an account with out-of-date information may be worse than having no account at all, as the lack of updated content may connote lack of activity within the relevant academic programs. Additionally, concerns about privacy and regulation of user inappropriate interactions may dissuade some users from engaging in social media. Many of the social media tools include tools that can help monitor for inappropriate content as well as banning users who are abusive. A final challenge with using social media is differential access to platforms. Some individuals may not have the technology to engage in social media on a regular basis or may choose not to do so because of privacy concerns. Placing content on one social media site does not guarantee that the content will be seen by a large audience. One positive aspect about social media is that most sites provide detailed metrics on user engagement which can help guide its management and usage and help administrators find content that will be most engaging to relevant audiences.

Best Practices

To promote effective usage of social media, several best practices should be followed. First,

users should clarify their goals for using social media. Is it to build connections with alumni or to connect with undergraduate students or to attract new applicants or a combination of goals? Second, administrators should be trained on social media usage and receive periodic training. Third, multiple social media platforms should be considered based on the desired goals. Content should be geared to the specific features of each platform; identical content posted across different social media platforms is likely to be ineffective. Regular content needs to be collected, created, and posted. Finally, metric data provided by social meeting platforms should be analyzed to help determine the effectiveness of various types of posts and content. For example, on Facebook pages, it is possible to determine how many people have seen a particular post, as well as the amount of engagement (e.g., likes, comments, and shares) associated with each post. These data can be used to provide feedback on social media strategy and used to guide future activity.

Conclusions

Social media tools can be useful for academic units to promote additional connections with students, faculty, alumni, and other relevant constituency groups. Existing research has focused on using Facebook pages and groups to connect with alumni and students (Farrow and Yuan 2011; Zickar et al. 2018). This research shows that people who are connected to academic units on social media feel connected to their department. Research also shows that content must be targeted to a particular audience's needs. Different audiences will react differently to content tied more directly to them (Zickar et al. 2018). For example,

undergraduate students will react more positively to content highlighting their accomplishments, whereas alumni react more positively to posts featuring fellow alumni accomplishments. Clearly, more research needs to be done on using social media to promote academic functioning.

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- [Facebook Use in Malaysian Higher Education Classroom](#)
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Value of Teaching Computer Science

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Introduction

Computer Science is the academic discipline that underlies all developments in Information Technology. A succinct but fairly comprehensive definition of Computer Science that reflects current understanding is “The scientific and practical approach to computation and its applications and the systematic study of the feasibility, structure, expression, and mechanization of the methodical procedures (or algorithms) that underlie the acquisition, representation, processing, storage, communication of, and access to information” (https://en.wikipedia.org/wiki/Computer_science). In recent years, reports from various countries have revisited the importance of all students learning Computer Science throughout compulsory education, following concerns about Computer Science being neglected in school curricula (Joint Informatics Europe and ACM Europe Working Group on Informatics Education 2013; The Royal Society 2012; Wilson et al. 2010). These reports emphasized the serious implications for economic prosperity of the decline in Computer Science learning but also mentioned the benefits to individuals and society

of people being well educated in Computer Science. The decline in teaching Computer Science in schools has happened in many, but not all, Western countries and has generally been associated with a focus on basic digital literacy at the expense of the study of the academic discipline (Webb et al. 2017). All of these reports into the demise of Computer Science (Joint Informatics Europe and ACM Europe Working Group on Informatics Education 2013; The Royal Society 2012; Wilson et al. 2010) recommended the learning and teaching of both Computer Science and digital literacy throughout compulsory schooling. Digital literacy enables people to use business applications such as spreadsheets and databases as well as to make safe and effective use of Internet-based technologies and thus enables people to be users and consumers of new technologies but not creators. Developing understanding and skills in Computer Science opens up a broad range of opportunities for creativity and innovation both for personal development and for employment prospects. Since these reports were written, many countries have reviewed and redeveloped their curricula, and there is generally a renewed focus on Computer Science (Webb et al. 2017). However, in the UK, for example, where a significant effort has been made to implement the recommendations of the Royal Society's original report (The Royal Society 2012), a recent report also by the Royal Society (2017) has found that the teaching of Computer Science in schools

is patchy and opportunities for learners to gain accreditation in Computer Science are still often limited. The main reasons identified for these problems were the lack of teachers qualified in Computer Science, lack of expertise to teach new courses, and limited access to appropriate professional development (The Royal Society 2017). In addition, concerns were raised about the qualification framework and the availability of good-quality research evidence regarding pedagogy. Therefore, the report has recommended very significant investment in teacher professional development on a level consistent with that in math and science education. Similar problems were identified by the International Federation for Information Processing (IFIP) Task Force on Computer Science in the Curriculum (Webb et al. 2015a, b). Thus, in most countries the teaching of Computer Science remains a significant challenge requiring substantial investment particularly in teachers. This article examines the arguments and reviews the evidence for the value of learning and teaching Computer Science in schools at various levels.

Rationales for Teaching Computer Science

The three main rationales for teaching computer science can be summarized as economic, social, and cultural (Webb et al. 2015b; Fluck et al. 2016). The economic rationale is well-known and frequently used to justify the need for Computer Science in the curriculum (e.g., see The Royal Society 2012). The economic rationale rests on both the need for a country to produce computer scientists to sustain a competitive edge in a world driven by technological developments and the need for Computer Science-enabled professionals in all areas of business and industry to support innovation and development (Fluck et al. 2016). The World Trade Organisation reported that in 2016, ICT was the fastest-growing category among commercial services other than travel and predicts that the future rise of new technologies will have a positive impact on digital trade (World Trade Organisation 2017).

In the UK, employers have reported an increasing need for computing skills (Employment, U. C.f., Skills 2014), and the UK together with the rest of Europe, as well as a survey of policies across most OECD countries, has described a “digital skills crisis” (House of Commons Science and Technology Committee 2016; European Commission 2017; Martin 2017). These digital skills are not just the basic digital literacy mentioned earlier but include programming and other computing skills that depend on Computer Science as the underlying academic discipline. While currently there is a need for basic computing skills, predictions of the effects of future technological development suggest the need for more advanced and creative skills, including the ability to innovate with technology, as a wide range of jobs become susceptible to computerization (Frey and Osborne 2017). Educating learners in Computer Science is therefore crucial for economic prosperity and is also an individual entitlement issue. Learners are entitled to have access to the “powerful knowledge” (Young 2013) that will enable them to take their place in society and enjoy good employment prospects.

The social rationale emphasizes the value in society of active creators and producers rather than just passive consumers of technology. Such capability empowers people to lead, create, and innovate with technology in society. Furthermore, understanding of the nature of Computer Science and how its applications, particularly in areas like artificial intelligence, may profoundly affect society, is important for people to be able to contribute to decisions about how new technological developments can best be harnessed to serve society and how their dangers can be avoided (Makridakis 2017).

The cultural rationale rests on enabling people to be drivers of cultural change rather than having change imposed by technological developments. Applications of Computer Science, including digital games, virtual reality, and augmented reality as well as the ubiquitous social media applications, have enormous potential for bringing about cultural change. At the same time, all of these technologies can be used to record and

preserve cultural traditions and influence how culture is portrayed and experienced.

In addition to these three major rationales for learning Computer Science, there are potential benefits for supporting the learning of other curriculum subjects and education more generally as will be discussed next.

Computer Science Supporting Education

There are many ways in which understanding and skills of Computer Science may support learning and education in other curriculum areas. These possibilities range across (1) understanding how Computer Science may support knowledge generation in many different subjects, (2) using programming and modelling skills to support learning about systems and phenomena in subjects such as science and geography, (3) using problem-solving skills gained in Computer Science to support problem-solving in other areas of the curriculum, and (4) using Computational thinking, developed in Computer Science lessons, to support learning in a range of subjects. Possibilities 3 and 4 remain controversial as discussed later in this article.

Computer Science has increased in importance for knowledge generation in a range of important areas of human endeavor, including areas as diverse as healthcare (Kunkle et al. 2016) and agriculture (Janssen et al. 2017). Thus, Computer Science is heralding new developments and is providing new methods for knowledge discovery (see, e.g., Adam-Bourdarios et al. 2015). Thus, understanding how methods of Computer Science, including big data and analytics, artificial intelligence, modelling, etc., are enabling knowledge generation is important for empowering learners to critically evaluate opportunities for new knowledge generation across many subject areas, especially in science and social science. There is also value for learners of actually engaging in the types of processes employed by scientists in order to understand how knowledge is generated (Evagorou et al. 2015). Increasingly such processes employ computer-based modelling and/

or big data analytics (e.g., see Janssen et al. 2017).

There is a long history of research into the potential benefits of learning programming for developing general thinking and problem-solving skills, but the findings of the earlier research were variable and inconclusive (see, e.g., Salomon and Perkins 1987). The key issue is whether or not transfer of such skills occurs between one context and another. Transfer of skills between disciplines and even between topics within a discipline is not automatic (Scherer 2016), and Salomon and Perkins (1987) explained the variation in results of earlier studies of the transfer of problem-solving skills from learning programming by whether or not “mindful generalization” had been employed as a pedagogical strategy. However, they also questioned whether or not programming was the best approach to develop general problem-solving skills. While there is conceptual overlap between programming skills and general problem-solving skills, there is a need for further empirical studies to examine transfer in current educational scenarios with the new generation of languages and tools for learning programming (Scherer 2016). The issue remains controversial, and the debate has been enlivened recently by the revised focus on computational thinking (Grover and Pea 2013; Lye and Koh 2014).

Computational thinking is about analyzing and solving problems and presenting solutions in such a way that they can be implemented on computers. According to Wing (2006), thinking in this way is so fundamental in the digital age that computational thinking should be regarded as another basic skill set alongside literacy and numeracy. While computational thinking does not depend on programming, Webb et al. (2015b) argued that computational thinking is best developed through Computer Science learning including programming since (1) the processes of computational thinking, for example, abstraction and decomposition, are also fundamental to Computer Science; (2) programming, especially with visual languages, makes an excellent vehicle for students to explore the concepts in a concrete way, and (3) implementing the concepts in a program provides a means for students

to check their thinking. As their expertise in computational thinking develops, students would be expected to use their skills and build their understanding of applications of computational thinking via a range of examples across different subjects. Thus, if computational thinking is to be developed through learning computer science and the claim of universal benefit (Wing 2006) is accepted, then it is possible that a significant value of learning computer science may be to develop computational thinking. However, the claims for computational thinking remain controversial. While there is no doubt that experienced computer scientists engage in computational thinking in order to design computational models and algorithms that can be used for computational solutions to problems, according to Denning (Wing 2006), the way in which computational thinking is defined in the literature remains a source of confusion. The nature of computational thinking, its value for students' learning, and methods of assessment are currently the subject of ongoing research.

Overcoming Barriers and Limitations to Learning Computer Science

Thus far, this article has argued for the value of learning Computer Science as an entitlement for all learners. Nevertheless, as many have argued, many Computer Science concepts can be difficult to understand. Furthermore, programming, which is considered an essential element of introductory Computer Science courses, is generally considered to be difficult to learn (see, e.g., Robins et al. 2003). Some, in Computer Science education, have therefore questioned whether it is appropriate for all young people to learn Computer Science. However, most educators would agree with Bruner that any subject can be taught to any learner at any stage in their development (Bruner 1960). It is a matter of simplifying concepts, using concrete examples, and revisiting ideas regularly in a spiral curriculum. Recent developments in visual programming

languages and other tools that support learning of programming as well as new pedagogical approaches, such as "CS unplugged," are making Computer Science more accessible to younger learners (Duncan et al. 2015).

Conclusion and Implications

In summary, the arguments outlined here present a strong case for students to learn Computer Science in schools. Developing the understanding and skills of Computer Science is an entitlement for all school students that will support them in taking their place in society, influencing cultural change and potentially supporting their employment prospects. Furthermore, economic prosperity depends on a workforce that is not only digitally literate but is also able to create and innovate with technologies within both the computing industry itself and across all areas of business and industry. At the same time, individual learning across many curriculum areas may be supported by understanding and skills developed in Computer Science. Whether this support for other curriculum areas is focused on the value of Computer Science for knowledge building and using programming and modelling skills or whether for the even broader value of developing computational thinking and problem-solving ability remains a subject for further research. Furthermore, enabling all students to learn Computer Science may be challenging and needs to be supported by more research into which pedagogical approaches are successful with which learners.

Cross-References

- ▶ [Computing Curricular Report CE2016, A Summary](#)
- ▶ [Computing Curricular Report IT2017, A Summary](#)
- ▶ [Computational Thinking](#)
- ▶ [Curricula in Computer Science](#)

- Learning Programming, Success Factors
- Teaching about Computing
- Teaching with Computing, Educational Games

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Value of Teaching PRINCE2 Project Management Methodology

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Synonyms

PMBOK; PRINCE2; Project management; Training

Introduction

As project management evolves as a field of practice, companies are now realizing that their entire business, including most of the routine activities, can be regarded as a series of projects. Simply stated, businesses are managing their transformations by projects.

There are a number of accepted approaches to project management, the Project Management Body of Knowledge (PMBOK) and Projects in Controlled Environments Version 2 (PRINCE2) being two of the most important. Recently there has been considerable interest in Agile Project Management.

Joslin and Muller (2015) found that there was a positive relationship between the use of project management methodologies such as PMBOK and PRINCE2 and project success. These are described as project management “best practices” by the respective “owners” which are the Project Management Institute (PMI) and AXELOS, respectively.

The teaching and learning of project management have attracted the attention of many scholars within project management professional education (Ojiako et al. 2015). There are a number of issues with the teaching of project management specifically to IT professionals which was described by Lecomber and Tatnall (2014). The authors made the distinction between education and training of project management. The fundamental difference between education and training

is that in education, the focus is to provide learning that lasts. “Education can be described as what remains after one has forgotten what one has learnt in school” (Albert Einstein). However with training, people are shown what to do rather than really ensuring that they understand the underlying theory. Training does not allow for reinforcing, monitoring, and encouraging which are necessary to ensure that real learning is acquired. With training, there are limitations in the way in which courses are delivered on learning outcomes.

This entry does not distinguish between education and training but seeks to communicate the value of teaching a particular project management methodology, PRINCE2.

PRINCE2 Project Management Methodology

PRINCE2 is a methodology for managing projects and has grown to become a de facto “standard” as a project management method in more than 150 countries worldwide (Sargeant et al. 2010). PRINCE2 was originally developed for the UK government to manage their IT projects and was based on soft systems methodology. The first version of PRINCE was published in 1989 (Sargeant et al. 2010).

A multidisciplinary research team from the Queensland University of Technology (QUT), financed by the former owners of the intellectual property of PRINCE2, the Office of Government and Commerce (OGC), undertook one of the first empirical studies into the impact of the PRINCE2 methodology on project performance (Sargeant et al. 2010). The research study was entitled “Creating Value in Project Management using PRINCE2” and also conducted parallel research on the impact of other unspecified (non-PRINCE2) contemporary project management methodologies.

The researchers interviewed PRINCE2 practitioners from a diverse range of industries (including Information and Communications Technology, Construction, and Transport) and across three major geographical regions (the

United Kingdom and Europe, the United States, and Australia) (Sargeant et al. 2010). The researchers found that PRINCE2 was perceived as a very robust, comprehensive, and pragmatic project management framework (Sargeant et al. 2010).

Problems and issues which impeded the adoption of PRINCE2 to projects were organizational and not methodological, and the dominant issue identified by participants was poor project sponsor/board performance and a reflection that organizations either do not know how or do not possess the commitment to properly implement PRINCE2 (Sargeant et al. 2010).

Wells (2012) explored the effectiveness in the workplace of project management methodologies including PRINCE2. Her research found that there was “a chasm between the intended strategic directions of the project management methodology and its actual contribution to projects, managers and their teams” (Wells 2012). According to Wells (2012), the purported benefits are often not realized or can have unintended consequences at the project level and adversely affect project success.

Furthermore, Wells’ (2012) research on project management methodologies showed that the methodologies were useful for those that were at opposite ends of experience and accountability for projects:

- The inexperienced in project management
- Those who were most senior in the organization who were focused on the governance of projects

In between these two ends of the spectrum, the “perceived benefits and advantages of using project management methodologies dramatically falls, to a minimum, corresponding to the middle ground of the range of perspectives”(p. 57), the drop largely due to the drawbacks and limitations that the practitioners experienced in adopting the methodologies (Wells 2012). In other words, those who had some experience of project management considered the use of a project management methodology to be an overhead in their day-to-day work and did not use it. It was only

useful for those who were inexperienced as it was a useful guide for them. It was also valuable for those very experienced who were also senior managers as they were looking for ways to control projects and implement governance across the organization by seeking a standard in delivering projects (Wells 2012).

Research Study: Longitudinal Case Study

A research study was conducted by Lecomber (2017) to understand how participants used and adopted the PRINCE2 methodology to workplace projects following a professional training course. The study, over 2.5 years, used case study as a method. The research formulated qualitative answers to the main research question: “How are practitioners influenced to apply PRINCE2 in complex and dynamic environments?”

The research focused on studying 16 staff across a broad range of departments within an organization from sales to IT. The results showed that there were some participants who adopted as much of the PRINCE2 methodology as they were able for their work projects and actively sought to improve their practice. Another group of participants had knowledge of the methodology but considered the overhead in using it far outweighed the benefit derived from using it.

To analyze these two different forms of adoption, Innovation Translation, informed by actor-network theory (ANT), was used. ANT enables the researcher to think in terms of different translations and to seek to identify the actors involved and the interactions that formed possible stable networks supporting those translations. Innovation Translation has the advantage of being able to explain examples of partial adoption and of situations where what is actually adopted differs from what was proposed (Tatnall 2009). This was particularly relevant for this study as it could be said that one group of participants made *only* a partial adoption.

ANT, also known as the Sociology of Translation (Callon 1986; Latour 2005), was developed by science and technology scholars

Michel Callon and Bruno Latour, sociologist John Law, and others. It is a conceptual framework for exploring collective socio-technical processes and aims to follow the actors in a given network in the process of new network formation (Latour 2005). Innovation Translation, informed by ANT, argues that an innovation moves along as a chain of consequence by energy given to it by everyone in the chain whose actions shape the innovation to suit themselves (Tatnall 2009).

Actors Involved Even Before Delivery of the Training

The actors involved include the trainer, trainee (learner), curriculum, and the workplace. There are actors at play even before Day 1 of the training course. These are AXELOS, the Examination Institute (APMG), and the Accredited Training Organization (ATO). The ATO provides the training material and the trainer. The ATO obtains the PRINCE2 manual from a bookseller who procures this from AXELOS, while APMG dispatches the exam paper. The nature of the outcome of the training experience is a result of the interaction of the human actors (the trainer and the other participants) and nonhuman actors (training materials, timetable, exam papers, PRINCE2 manual, and training venue). After the training, the participant project manager seeks then to adopt the innovation in the workplace. This research study seeks to understand both the interactions that occur during training as well as in the workplace after the training course with respect to the adoption of the PRINCE2 methodology.

Understanding Adoption in Terms of Translations

Callon (1986) defines four moments (stages) of Innovation Translation: “problematization,” “interessement,” “enrolment,” and “mobilization.” The four stages, if successful, lock the actors into the network and create a stable translation (Davey 2014). This research looked at adoption in the form of two different translations:

1. Some participants adopted as much of the PRINCE2 methodology as they were able for their projects and actively sought to improve practice. The study named this adoption as

the Performing Translation (**PT**). Those who had adopted **PT** had a focus on continuous improvement in their practice. Those who adopt the **PT** are people who keep attempting to apply their learning and hence learn more. In addition, those who adopted the **PT** conducted their own research into “best practice” outside of work hours.

2. The other group of participants who had knowledge of the methodology but considered the overhead in using it far outweighed the benefit derived from using it formed the Knowing Translation (**KT**). A **KT** sees nothing in the formal structures of PRINCE2 that is so valuable that they would sacrifice early delivery by going through procedures stated in the methodology. Those who had adopted the **KT** would only apply what they had learned to the workplace if they perceived adoption across the organization.

In the case of **PT** participants, as their organization did not have the supports such as strong leadership for using a methodology and a strong Project Management Office (PMO), some participants who adopted the **PT** eventually resigned from the organization. In this research study, the PMO was weak and could not enforce the governance needed to support the use of PRINCE2.

Participants whose form of adoption was the Knowing Translation (**KT**) had knowledge of the project management methodology but considered the overhead in using it far outweighed the benefit derived. The lack of support from the top-down commencing with the senior leadership team and the original sponsor of the methodology had a strong influence on those who adopted the **KT**. A senior leadership team and sponsor must go beyond paying “lip service” to the methodology and actively comply with the methodology in terms of behaviors, responsibilities, and expectations of their role on the project as sponsors and project board members.

Implications

The research results by Lecomber (2017) identify two adoption outcomes as a result of

project management training which could be used to assist organizations in their strategies to support embedding of learning outcomes following project management training. These results are congruent with the research conducted by the Sargeant et al. (2010) study which showed that problems and issues which impeded the adoption of PRINCE2 to projects were organizational rather than methodological.

The value of professional vocational education and training in project management depended on what structures were in place in the organization to support the adoption of the project management methodology. These supports include:

- A strong Project Management Office (PMO)
- Senior leadership team that supports the use of the methodology
- Strong visible support by the sponsor of the methodology

Conclusion

In the study conducted by Lecomber (2017) which was based on PRINCE2, the emergence of two possible adoption outcomes has implications on how organizations derive value from their investment in professional project management education and training regardless of the methodology used. As well as ensuring that the project management education is performed well, it is important that organizations commit to supports in place such as a strong PMO, senior leadership supporting the methodology, and strong visible support from the sponsor if the organization wishes to derive the value from the project management training. Otherwise the investment in teaching project management is a “waste of money.” This is particularly important in the education of IT professionals.

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Values

- [Digital Citizenship, A Sociocultural Snapshot](#)

Victoria

- [School Management Software in a Primary School in Victoria, Use of](#)

Video

- [Digital Storytelling, Information, and Education](#)

Video in Schools

- [Video-Enhanced Feedback](#)
-

Video Making

- [Educative Value of Digital Storytelling](#)
-

Video Management

- [Video-Enhanced Feedback](#)
-

Video Streaming

- [Assisting People Who Are Deaf or Hard of Hearing Through Technology](#)
-

Video-Enhanced Feedback

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Synonyms

[Feedforward practices](#); [Filmed feedback](#); [Mobile video](#); [Video in schools](#); [Video management](#); [Visual feedback](#)

Introduction

Technology-enhanced feedback to students comes in many forms now that technology has become immersed in all aspects of the educational

process. Higher education institutions are criticized by students for the poor feedback practice (Boud and Molloy 2013), yet they, like other educational organizations, have access to video-enhanced feedback through the use of mobile devices. This chapter describes how video captured on mobile devices can play a part in a video-enhanced feedback process. The chapter is organized in three sections. First, video feedback in schools and higher education, then the processes employed in video-enhanced feedback, and finally the management issues related to the use of video to enhance feedback.

Video capture technologies are now readily available and have a broad acceptance among students and are accessible to educators worldwide. This chapter describes the use of video-enhanced feedback to build on the idea that it offers a richer format than audio and written feedback alone (McCarthy 2015). This has implications for practitioner across all contexts of education. In addition, this chapter focuses on the use of video in the feedback process because feedback has been clearly identified as having an impact on educational outcomes (Hattie and Timperley 2007) across all sectors. There are different forms of technology that are being implemented and made available to educators across the sectors, and mobile devices are becoming part of strategic planning in some jurisdictions and context.

Video Technologies in Schools and Higher Education

The type of technology (mobile, desktop, tablet) used is dependent on the educational context. Assessment feedback in primary education would typically use different technologies to those being used in secondary and tertiary education. Technologies available in most school settings within Australia include some form of commercial learning management systems (LMS) and/or commercial products, such as those found on the app stores, and bespoke practitioner generated systems.

Learning management systems are available to schools and higher education institutions.

They provide their users with multiple opportunities to engage in feedback and engage with multimedia tools such as video. Learning management systems also provide their users with a level of security and system-wide support which is a critical component to ethical educational practices while enabling a community of practice within which students and teachers can operate because of the stability it provides to the learning environment. A number of plug-in solutions that allow users to incorporate video into these learning management systems exist although it's only relatively recently that these add-ons have allowed for a video to become part of the assessment feedback.

In addition to the learning management systems, there are a plethora of commercial products sitting outside the scope of the educational institutions. These products are often heavily marketed into the educational space and provide users with opportunities to enhance their feedback practices and can include video. These enhancements often come at the cost of the practitioners' time, effort, and financial commitment because these systems sit outside of the supported learning environment promoted by their institution. Commercial feedback products can now be found for all types of systems such as Windows, Macintosh, and UNIX, but few have video as their central evidence point. They can also be found in the major application stores for mobile devices. The trouble here for practitioners is that these systems have mobile versions as well as desktop versions and that the versions change as improvements are made.

The final type of technology available to enhance video feedback is a bespoke system that may be generated from and by practitioners in the field. These systems are often research based, poorly supported by the institution, and require effort to overcome barriers of acceptance (Boud and Falchikov 2005). As such these are rarely implemented at a system level and rarely face the rigor of commercialization. These investments are unique, and while driven by practitioners who have an intimate knowledge of their feedback assessment requirements, they represent a small minority of the systems currently being used to

place a video in the feedback and feedforward assessment process.

Processes of Video-Enhanced Feedback

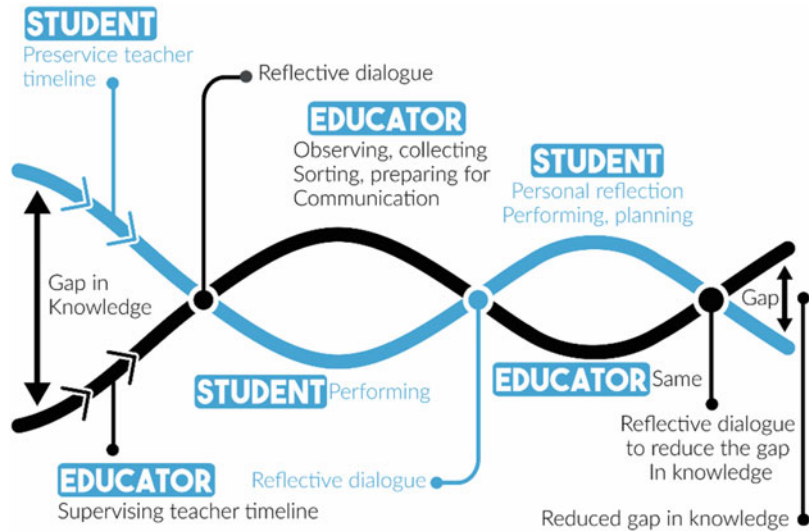
Sitting within this context is the complex task of integrating video into student feedback opportunities. One of the key drivers of this particular task is the idea that when students are empowered and can reflect openly and freely in a risk-free environment, they will generate a clear understanding of their progress toward their learning goal. The word empowerment is often synonymous with the word personal and ownership. These two concepts relate directly to the use of mobile devices. Mobile devices are often a personal device of an individual and customized by the individual to meet their particular needs. Information kept on this device is, therefore, personal, private, and accessible only to those people that the individual chooses. This allows the user to maintain ownership. The use of these devices for feedback processes can be a powerful tool if the student understands and accepts the positive learning outcomes that can be achieved through their use.

The increasing capabilities of video-enabled devices in terms of storage of material, connectivity with other devices and advancement in camera and voice recording capabilities, make them an opportunity for the enhancement of feedback in the learning and assessment process. This leads to exploring how tablets, phones, and personal wearable equipment might be used to enhance the video feedback process for students.

Exploring video technologies and their enhancement requires a framework for discussion of the video feedback process. Figure 1 shown below is one such framework.

The diagram identifies two key players in the feedback process. The educator and student are both involved in different ways within this process according to the image. This image is drawn from research around teacher education but is being adapted here to guide discussion about the place of video. The two lines in the diagram represent the two individuals involved in the

Video-Enhanced Feedback, Fig. 1 Video-enabled dialogue process (Dann and Dann 2018)



process. The lines start in separate places to represent the “gap in knowledge” which is the intended learning goal. The individuals’ paths cross at times when they speak or communicate about what they have seen or done depending on the perspective. This is called the point of reflective dialogue (Dann et al. 2018). If we use video and allow students to collect video to enhance this reflective dialogue, a number of issues arise which will be discussed further in this entry. Essentially, a student may be collecting video evidence of practice, demonstrating knowledge and performing skills while the educator is observing, documenting, sorting, and aligning information to the intended learning outcomes. Traditionally students receive information in text or voice recording formats, but now with the influx of technologies such as mobile video-enabled devices in the learning environment, it is common for students to be observing collecting and sorting through information collected or viewed on their mobile device about their learning. This is now part of the dialogue between themselves and the educator working with them. This new information is in the back pocket or hands of the student and the educator. This offers increased accessibility to the video of the student performance tasks, thus increasing the opportunities to discuss the contents of this video in order to reduce the “gap in knowledge” that the student has.

Processes of Technology-Enhanced Feedback

Video use can be supportive of the learning environment in this new age of mobile devices. There are a couple of key issues to consider. Firstly, the purpose of the assessment and the role students are given during the assessment process become central to the success of any feedback. As mentioned earlier, assessment types such as essays and tests do not lend themselves to the use of video, particularly video captured on mobile devices. A video is more engaging when used in performance-based activities. Secondly, there needs to be a clear link between the learning outcomes of the assessment and the possibility of seeing and providing formative feedback to students through video captured. This link between performance and learning outcomes needs to be understood by both students and educators (Bennett et al. 2017). Once there is a clear link, the third issue is the need for structured and systematic processes that link the assessment activity and any subsequent video of activity directly to some of the assessment criteria. This provides information for the students to share with peers and their educator/teacher. This raises the question as to whether or not the student viewing themselves or their peers have the knowledge base to provide clear definitive commentary about the

success or failure of the student attempting to demonstrate some skill or knowledge.

When learners are empowered to participate in their learning and strive for excellence in their assessment through a culture that develops assessment literacies, mobile devices can play a role. Capturing video evidence with a mobile device is only part of the process if the assessment task has components of performance and/or demonstration of skills and knowledge. The figure above shows a gap in knowledge that is initially set up by an assessment task. This gap is represented by the learning goal. The learner and the educator come together and discuss their understandings and perceptions of the task and the demonstrable skills that will indicate progress towards the goal. Once this event has occurred, the learner is then able to observe others and have peers observe themselves and record this activity with video captured on a mobile device as part of this process. The next time the learner and educator come together, the video can become a valuable piece of evidence for both to view and discuss. The discussion of the video increases the potential for the learner to identify unseen or unknown actions and behaviors (Dann and Allen 2015) and also allows both student and educator to explore actions and opportunities for increased performance. This ongoing action planning informs the dialogic conversation.

Using video changes the dialogue between learner and educator. It introduces a reference point that would normally have been the written observations or images of the lesson and, at the worst, memories from the performance without supporting annotations. Each of these types of evidence requires the educator to respond and guide the student toward the learning outcomes. The words and actions of the student within these videos can now be examined by both the educator/teacher and the student. This connection can become the model for peer-to-peer engagement with other video evidence in their attempts to improve.

The space between the educator and the learner after the dialogue is critical for both to reflect and consider their ongoing attempt to achieve their learning goal. There has been significant work

conducted in the peer feedback space (Ajjawi and Boud 2017) and the increased emphasis on student satisfaction and the personalization for learners in education (particularly higher education) due to the preference of students for this over general feedback (Cramp 2011). This brings the use of personal devices into the scope of educational support tools. Building opportunities to engage learners with their practice and model good coaching and networking practice and strong dialogue between learner and educator can be enabled and enhanced by the use of video captured on personal devices.

Further research has shown that actively engaging with the videos through reflective practice can also improve learning outcomes for learners in higher education. This engagement can be through viewing and discussing, viewing and coaching methods, viewing in personal reflective quiet spaces, and also viewing, editing, and adding reflective commentary to the video file. The increased number of video editing systems freely available to students further enhances the possibilities and value that video can add to the formative assessment processes and even the summative assessment process.

One key to the effectiveness of the video use is the alignment of the video to the learning outcomes and the structures provided by the educator. Structure equates to processes and procedures for users. The use of video requires structure around what is videoed, to ensure that the video content is relevant to the learning. Structure in the process of time and volume of collected video to ensure participant acceptance of the video capture. Finally, due ethical considerations require a structured approach to account for how to work with video that might include a vision of others. Each of these elements requires the attention of educators who plan on using video-enhanced feedback captured on mobile devices.

The mobility of the device brings with it many ethical dilemmas for the educator who is choosing to engage with the opportunity. These dilemmas include the immediate storage of the video, the security of this storage, and the access to the video. The use of personal devices by a student overcomes many of these ethical issues until

others are included in the video that is captured. When others are involved, then there are a number of issues to be considered regardless of your activity being research or purely for personal assessment and learning. It is important to note that a student may have different views of video use to the teacher and the teachers' ethical responsibility is to manage these views. These ethical issues relate to the privacy of individuals, and these differ depending on the location of the video capture. Be aware that privacy now relates to the analytics of student use and access (Pardo et al. 2017). Specific ethical requirements from the institution about the following aspects should be sought prior to instigating research into mobile video capture for enhanced feedback.

The Storage Requirements of the Video

Mobile video captured is often stored directly on the device, but some individuals have automatic cloud-based backup, and each device has options for the storage of the video. Particular attention needs to be given to the storage of video on cloud servers as these have various access and ownership policies that are important considerations. As an example, Australian researchers collecting video in Queensland are not able to have any data stored on servers outside of Australia. This means that the common cloud servers attached to major brands such as Apple, Samsung, and Nokia need to be explored if the video is going to be stored on these servers.

The Transmission Requirements of the Video

The capture of video on devices is a simple process, but the length of video collected and the resolution of the video capture device has a direct impact on the files size created. The file size may impact on how you choose to store and/or share the file. If you are choosing to share the video over an open-access Wi-Fi environment, then you will need to consider the security and access to that environment. Departmental wireless environments are typically locked down to accredited users, and therefore protocols are already in place for those who may access the video. If the device is a personal one and is not connected to a

systemic environment such as a department or an organisation, then consideration may be required as to how to transmit the file(s). Transmission over open telecommunication networks can be quick and are less secure than those previously described. These issues require consideration if you have private information or the video contains vision of children or other material considered sensitive.

The Security Over the Video Access

Once the video is stored, access to it needs to be controlled by the creator. General access to private devices is often controlled by the owner of the device and this can vary. Bluetooth access and access to the device by others need to be considered dependent on local requirements. Generally, this would not be an issue, but depending on the scale of the use being sought, this still needs consideration. Key to this issue is the scale and systematic implementation of the video process. Placing a personal device in an assessment process requires the educator to have a clear vision of the processes and products that might be created and how the learner and other learners will interact with these.

The Requirements of the Location in Which the Video Is Being Taken

When discussing location in our localized world, we need to be conscious of the numerous locations that might be involved. Online coursework or even on campus coursework can involve any number of locations. The authors' work was positioned within teacher education which involved the classrooms at schools and spaces within the university. Implementing a program of mobile video in a teacher education context or even a nursing or science program may involve learners going off the grounds of the university to visit and learn. In this case consideration of the local hardware and software requirements needs to be considered. Some sites may have a strong secure Wi-Fi environment, while others may not, and this could result in difficulties for learners who cannot undertake the processes set up by the educator. Further to this is the need to understand the ethical

and organizational constraints of the learners' new environment. Some organizations may only allow video to be collected by their own organizational approved and linked devices and may not allow personal devices in any form.

Each of these ethical issues needs consideration to embark on a mobile video collection program for increasing dialogue between educators and learners or even between learners. The movement to mobile devices has challenged educators and will continue to provide conundrums for educators and learners as the functionality changes and advances. Video capture on mobile devices has been shown to play a role in the feedback and assessment literacy of learners, but the systematics and protocols of the educator and their respective organizations need to be clearly articulated and understood.

Conclusion

Video-enhanced feedback is a phenomenon that is constantly changing and requires educators to maintain the currency of practice and to explore the evidence-based research that exists in order to ensure quality learning outcomes. The role of the educator is to ensure a balance between the demands of the students and the resources available to the educator. If this balance is achieved within a holistic view of the learner, then it is very possible that video-enhanced feedback will enrich the learning of students who are able to engage in this practice.

Cross-References

- [Beginnings of Computing in School Education in Australia](#)
- [Mobile Computing and Mobile Learning](#)
- [Mobile Learning](#)
- [School Management Software in a Primary School in Victoria, Use of](#)
- [Teacher Education, Thinking About ICT](#)
- [Technology Enhanced Learning](#)

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Visual Impairment

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WalkAbout Framework for Contextual Learning Through Mobile Serious Games

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Synonyms

Contextual learning; Mobile learning; Technology enhanced learning; Ubiquitous learning

Introduction

Mobile technologies are increasingly being incorporated and disseminated in education. Their resources promote social interactions and communication facilities due to Internet connectivity and other programs that can be used in the teaching and learning process. These new technologies associated with the processes of collaborative learning stimulate the classes, encouraging the students to think through the interaction between them and the teachers in the resolution of challenges and problems (Fojtik 2014).

Mobile devices such as smartphones, tablets, and other gadgets can be used anywhere and offer many applications and features that allow interaction and communication between users. One of

the applications that can be used with these devices is the mobile educational digital games (Parise and Crosina 2012). These games have a high amount of content and different levels of challenge that promote the intellectual development of students.

Mobile educational games when used in a collaborative learning approach can streamline the teaching process. According to Laamarti et al. (2014), the inclusion of collaborative activities with the application of mobile games improves acquisition and knowledge and fosters the development of various skills such as self-learning, problem-solving skills, critical capacity improvement, and socialization.

Collaborative learning assumes that the construction of knowledge is carried out by means of social interaction, contributing to the development of social skills and also enables greater involvement with content, exchange of ideas, and formulation of new perspectives. According to Le et al. (2018), using the collaborative methods of teaching the student becomes active and participatory in the learning process, making him assimilate concepts and information, facilitating the construction of knowledge through interaction with other individuals.

Despite the unequivocal advantages associated with the adoption of mobile educational games, several challenges must be considered to create contextual learning experience. Several research questions emerge as relevant, such as:

RQ1: How can we create immersive learning environments?

RQ2: How to facilitate the interaction with the natural environment?

RQ3: How can we facilitate the interaction between students?

RQ4: How can we transmit the feeling that the user is controlling their games?

RQ5: How can we assure that the game is effectively helping students in their learning process?

In this sense, this study presents a novel framework and associated learning process to produce contextual learning mobile game systems that look and respond to the identified issues above. This entry is organized as follows: initially a literature revision on serious games, contextual learning, and mobile learning is performed. After that, the adopted methodology is presented. Consequently, the results of this study are analyzed and discussed. Finally, the main conclusions are drawn.

Serious Games in the Learning Process

Game-based learning uses gaming as a tool for students to engage in learning while playing. According to Prensky (2013), learning based on digital games is based on two premises: (i) students have changed their way of searching and acquiring knowledge and (ii) these individuals are from a generation that grew up experiencing games, such as computer games and video games. This new form of entertainment shaped preferences and abilities, and offered enormous learning potential for both children and adults. Game-based learning drives innovation through education, hence the importance of engaging a broad community as educators, designers, programmers, researchers, and students at all stages of the process and implementation of this approach (Bakan 2018). Serious games have been successfully adopted in different domains of education, such as management, entrepreneurship, computer science, or languages training (Almeida 2017; Alyaz et al. 2017; Buzady 2017; Yassine et al. 2017).

By using games for educational purposes, various aspects of the learning process are supported. Students are encouraged to combine knowledge from different fields to make a decision or choose a solution among several options; students can choose how the outcome of the game changes based on their decisions and actions and, ultimately, they are encouraged to interact with other team members, discuss and negotiate subsequent steps, and thus improve their social skills (Buzady and Almeida 2019; Foster 2011).

Panisoara et al. (2015) state that one of the key aspects of effective learning is motivation, which needs to be sustained through responses, reflection, and active involvement in order for learning objectives to be met; it is important to have a balance between an exciting game path and properly completed learning. The players have to feel realism, challenge, opportunity of exploration, and control. According to Bawa et al. (2018), multiplayer games are one of the most powerful forms of motivation, enabling group replication of situations and conflicts under different conditions and configurations.

Contextual Learning

Context can include many aspects or dimensions, such as location, date, time, personal and social activity, resources, and goals and task structures of groups and individuals. Context-aware computing has established a variety of context definitions, mostly starting from location or object context. Johnson (2002) advocates that contextual learning and teaching is based on the discovery that students find meaning in their schoolwork when they join the content of academic subjects with the context of daily life. Zimmermann et al. (2007) give a pragmatic definition of context. For them, context of a person or an object can be defined by five distinct parts:

1. Identify context – includes information about objects and users in the real world. With respect to users, their profile can include preferences, acquired-desired competences, learning style, etc.

2. Time context – ranges from simple points in time to intervals and a complete history of entities.
3. Location context – splits into quantitative and qualitative location models, which allow working with absolute and relative positions.
4. Activity context – reflect the entities goals, tasks, and actions.
5. Relations context – captures the relation an entity has established to other entities and describes social, functional, and compositional relationships.

Contextual learning has the power to help student's process, because new information that is given to them in a way that makes sense according to their own world of memory and experience (Suryawati and Osman 2017). The importance of this type of learning is that the student's mind naturally seeks meaning and context in the subjects they are being taught. Therefore, Rosa et al. (2017) state contextual diversity facilitates the learning process. At the same time, this type of learning can occur in a number of different places: in the classroom, a laboratory, a computer lab, outside, or in a place of work (CORD 2001). Due to the flexibility of this type of learning, a teacher can design a learning environment, which incorporates many different forms of experience, including social, cultural, and psychological.

Mobile Learning

There are various definitions of mobile learning but no one is generally consensual. Dewey (1996) was the first one to address this issue and defines mobile learning as “a society which is mobile, which is full of channels for the distribution of a change occurring anywhere, must see to it that its members are educated to personal initiative and adaptability.” Ally (2005) defines mobile learning as “the delivery of electronic materials on mobile computing devices to allow access from anywhere and at any time.” More recently, Basak et al. (2018) advocate “m-learning is the subset of e-learning through mobile computational devices.”

Commonly mobile learning has often been viewed as learning mediated through mobile technology. Due to the progress in the field of

broadband communication, it is nowadays possible to use network connections nearly everywhere thus allowing a user to be online all the times. Additionally, while the computational power and the storing capabilities increase, the size of today's mobile devices decreases. According to Bosomworth (2013), the market for mobile devices is growing more and more and in 3 years it should take over desktop internet usage. This mobile revolution is changing everyday life and offers new ways of learning. This also enables educational institutions and teachers to harness mobile learning solutions to offer more effective and richer learning experiences.

Mobile learning has some attributes that depend on the user: the user's environment and the used technology or device. It is a very time-constrained task delivering context-oriented content. Learning is normally done on-the-fly, which means that it is very fast and occurs mostly during spare time. Thus, the information provided has to be personalized to the needs of the user. Combining contextual and mobile learning, we can use context information to choose the most appropriate information or learning material. Furthermore, mobile learning includes multimodal interaction using several technologies handled on the mobile device, like speech recognition, sound, touch gestures, etc. (Pisey et al. 2012; Kaliisa and Picard 2017). Lastly, mobile learning can also support collaboration, where the user contacts their fellow students, friends, or experts (Pedro et al. 2018).

Being mobile adds a new dimension to the activities that can be supported, both because of the personal and portable nature of the devices themselves and because of the kinds of interactions they can support with other learners and the environment. Klopfer et al. (2002) identify five properties of mobile devices that produce unique educational affordances in terms of portability, social interactivity, context sensitivity, connectivity, and individuality.

Mobile learning provides a potential way forward for the expansion of education programs to larger segments of the population rather than via the traditional eLearning model that has been adopted in much of the developed world. Valk et al. (2010) states that mobile learning allows a

method of educational delivery that could be more cost-effective than e-learning methods, not to mention that the ubiquity of mobile phones means that many people are already familiar with mobile phone applications.

However, if learning is to have a deep impact in the learning process, there are still several issues that should be properly addressed and considered. The former is the need of supporting temporal mobility. Dispersion in time makes it hard to define precisely the start and end of a mobile learning session. Learning scenarios should consider this aspect and support not only the spatial mobility of students but also their temporal mobility (for example, by giving the opportunity to easily stop and resume a session) (George and Lekira 2009). The latter is the importance to integrate mobile applications into global learning systems. The idea here is to let the learner easily switch between a desktop application and a mobile application. For that the user interface should be adaptive and the information gathered during mobile use should be reused on desktop applications in order to adapt the learning game to each learner experience (Cochrane 2010; Paredes and Ayala 2012).

Ubiquitous Learning

Ubiquitous learning (u-learning) in contrast to mobile learning is not necessarily bound to mobile devices. In general, u-learning is enabled by an environment that can be accessed in various contexts and situations. As Van't Hooft et al. (2007) states, u-learning involves learning in an environment where “all students have access to a variety of digital devices and services, including computers connected to the Internet and mobile computing devices, whenever and wherever they need them.”

Students in u-learning environments have the potential to increase their learning experiences because they can critically weight their peers' ideas, react more intentionally, and check the accuracy of their opinions or assertions (Chin et al. 2018). Students benefit by using the opportunity to engage more thoughtfully than they often do when called on to respond on demand in a classroom or on an in-class exam. Similarly,

teachers have more flexibility in the way they interact, with the capacity to tailor subsequent lessons and responses to meet students where they are, individually and collectively (Yang 2006). According to Pimmer et al. (2016), positive outcomes of ubiquitous learning appear mainly with instructionist and hybrid designs.

Yahya et al. (2010) advocate that u-learning should have the following characteristics:

- Permanency – the information remains unless the learners purposely remove it.
- Accessibility – the information is always available whenever the learners need to use it.
- Immediacy – the information can be retrieved immediately by the learners.
- Interactivity – the learners can interact with peers, teachers, and experts efficiently and effectively, through different media.
- Context-awareness – the environment can adapt to the learners real situation to provide adequate information for the learners.

Ubiquitous learning can be about the adoption of appropriate technologies for use in traditional education environments such as classrooms, or it may be about the alignment of ubiquitous platforms with more ubiquitous contexts of learning outside the formal classrooms, like in workplace, in the home, or in public places.

Educational-Game Design Process

Learning can become more effective if it becomes contextual, mobile, and ubiquitous. Cordova and Lepper (1996) demonstrated this concept by using some educational tasks, where learning embedded in a motivating setting improved learning outcomes and that engagement can facilitate learning. More recently, George and Serna (2011) structured the classification of activities around the main theories and areas of learning relevant to contextual mobile scenarios:

- Behaviorist – activities that promote learning as a change in observable actions.
- Constructivist – activities in which learners actively construct new ideas or concepts based on both their previous and current knowledge.

- Situated – activities that promote learning within an authentic context and culture.
- Collaborative – activities that promote learning through social interaction.
- Informal and lifelong – activities that support learning outside a dedicated learning environment and formal curriculum.
- Learning and teaching support – activities that assist in the coordination of learners and resources for learning activities.

George and Serna (2011) established that for the creation of a successful game-based learning opportunity, the following steps of game design, elements of learning, and engagement should be taken into consideration:

- Determine pedagogical approach – when designing an educational game, we have to reflect upon didactical approach and related topics.
- Situate the task in a model world – students should be able to discover meaningful relationships between abstract ideas and practical applications in the context of the real world; concepts are internalized through the process of discovering, reinforcing, and relating.
- Elaborate the details – educators should choose and design learning environments that incorporate as many different forms of experience as possible (social, cultural, physical, and psychological) in working toward the desired learning outcomes.
- Map learning activities and concepts to interface actions and objects – the idea is to create polished products and activities valuable in their own right, enabling the learning process to occur in a real world scenario.

There are many interactive learning techniques that have already been used in game-based learning. According to Prensky (2013), one of those techniques is “learning from mistakes,” where failure is considered a point where the user gets some feedback. In game-based learning, making a mistake is a primary way to learn and is considered the motivation for players to keep on trying. Additionally, students should also be able to

assess their own activities to see how they are doing and to be able to evaluate their decisions and actions. There must be a close link between action and feedback, which will motivate students to keep playing the game (Westera 2019).

The Walkabout Initiative

Design-based research was the main method applied in this project. Based on the teaching, coaching, and managing experiences of the participating lecturers, a rough working method was set up in which different teams of students needed to collaborate. As a part of the working method, students were free to team up. Only one specification was given, each member must come from a different country. Initially, eight groups of five (or four) students were formed and were assigned a mentor. The resulting teams were quite different in formation. One team had only male students, and another team was mono-disciplinary. All teams were then formally informed on the task at hand to build a mobile contextual learning game given the context of the park with its themes and animals. From that point forwards an iterative process of mentoring and giving feedback started. Each morning all mentors briefed each other on the current developments and the overall impression on the progress of the project. During the day, all teams were briefed and coached by their mentors.

Within the whole group of students, two subgroups were identified. The Tech group was responsible for the technical development of the game. On the other side, the Art group was responsible for the learning and multimedia contents. Both groups were regularly called to meet as a group with the Tech mentor and the Art mentor. During those meetings training, feedback and specific instructions were given. The training sessions addressed issues as understanding the gaming system, taking leadership, teambuilding, and project management. The members of the Art group were instructed to take leadership over their team, and these team leaders were informed on the long-term and the short-term schedules.

WalkAbout IP ran for 10 working days, which is a short time to produce a full scale contextual

learning mobile game. Therefore two schedules, one short term and one long term, were defined. The long-term planning spanned the 10 days of the project and specified two sprints of 4 days. The short-term planning was a day-to-day planning for the game development, game presentation, and the feedback on the teams' progress. At the end of the first sprint, a game demo was presented; after the second sprint, the teams needed to demonstrate indoors a playable game using a mobile device (tablet or smartphone). During the last day of the IP, all teams evaluated the working games in the field. Due to the design-based approach, the team of lecturers was able to correct and steer the flow of the project.

As the project provided a real educational context, its results can effectively be used to improve practice in at least a likewise context. The iterative interventions, using mixed methods as training and assessments during the project, were constantly evaluated for their effectiveness. The evaluation was done by continuously checking the impact of the interventions on the teams' progress and the feedback coming back from the students.

The event took place at the Biological Park of Gaia, which is a small nature reserve center on environmental education. It has a natural

discovery course of about 3 km where the visitors can see more than 200 species of animals mainly of the Iberian fauna, either in captivity or in freedom.

The Park plays one of the most important functions of the green zones, the contact with nature source of psychological balance. This function is enhanced by the Park's apparent spatial disorganization resulting from the refusal of the formal garden or park model. Biological Park tries to preserve the typical landscape of the region, while it was essentially a large agricultural area.

A key objective of the Park is to point out the need to plan the territory, to maintain large green spaces in the cities, and to protect rivers, fauna, flora, traditional construction, a set of referential values of our civilization. Environmental education is a process of captivating and involving the citizen in solving the environmental problems that afflict humanity; a good way to begin this process is by demonstrating the contradictions of the great city and what it means for each of us in terms of quality of life.

Teams may place contextual serious games in each of the 18 points of the Park (Fig. 1), which includes: (1) host center, (2) picnic area, (3) exposure "from the rainforest to the desert,"



WalkAbout Framework for Contextual Learning Through Mobile Serious Games, Fig. 1 Map of Biological Park of Gaia

(4) estuarine birds, (5) badgers and otters, (6) kites, (7) Santo Tusso's farm, (8) exhibition "mills and implements," (9) foxes, (10) wild goats and wild boars, (11) bucks, (12) Bogas's farm, (13) European bison, (14) Chaso's farm, (15) day-time prey, (16) lake, (17) waterfowl, and (18) Cunha's farm.

Evaluating the WalkAbout Initiative

Part of the project was intended to analyze the perception of learning while performing a specific task in a specific setting. The setting was an international interdisciplinary team, and the task was to build a contextual learning game. During the IP, the students were asked to fill out two questionnaires. Two sets of questions were proposed to a group of (Finnish) students during a quantitative research methods course, and they derived the final sets of questions which were implemented in the questionnaires.

A total of 31 students from our initial group of 40 filled the questionnaires. Six students of 31 responses answered they had already worked in an international interdisciplinary team. These students all indicated that such a team is a powerful working environment although communication and language barriers are the main problem in such a team. Four of these students mentioned they had learned a lot through synergy.

Of those students (25 of 31) who had never worked in an international interdisciplinary team, 22 think working in such a team is very useful, although, they all expect communication and language to be a problem. Almost all (20) are anticipating learning to collaborate with other people, having a different education, different culture, and different opinions.

Except for one student, none had ever built a mobile contextual game. Twenty-seven students (of 30 responses) have the opinion that one can learn a lot through building a contextual mobile game. What students think they will learn is very different. Most expectations lie in the line of the student's current program. An IT student expects to learn more on JavaScript and mobile technologies, a student from teacher training expects to

WalkAbout Framework for Contextual Learning Through Mobile Serious Games, Table 1 Topics expected to learn by students

31 responses in total	Absolute frequency	Relative frequency (%)
Language	14	15
Social	9	10
Communication	17	18
Team work	21	23
Technical	17	18
Management	6	7
Creativity	7	8
Presentation skills	1	1
Other	0	0

learn how to deliver learning content in a more appealing manner, and, finally, most students expect to learn to collaborate with people. Only a few students (2 of 30) expects to learn something on games/puzzles/challenges and how they are built, one student thinks he will learn something from the context, and five students mention teamwork, time management, and organization.

When offered a choice of what they expect to learn during the IP, they answered as follows in Table 1. Each student was asked to choose maximum three topics. A likewise question about the topics learnt by students (Table 2) was asked in the second questionnaire. In two questions, students were asked how they experienced relations between teams in terms of competition and collaboration. To the question "How did relations between teams influenced your team [Competition]?" 1 student answered "A little bit in a bad way," 17 answered "A little bit in a good way," and 12 said "Strongly in a good way." In relation to the question "How did relations between teams influenced your team [Collaboration (did your team receive help from other teams)]?" 3 students answered "A little bit in a bad way," 13 students answered "A little bit in a good way," and 12 students said "Strongly in a good way."

In an open question on the quality of the teams, some students complained that their team with fewer disciplines (7 IT students and 1 non-IT) was considerably weaker in comparison to teams with a richer spread of disciplines (IT, tourism, and teacher training).

WalkAbout Framework for Contextual Learning Through Mobile Serious Games, Table 2 Topics learnt by students

What did you learn? 30 responses in total	Nothing	Superficial (a little)	In depth (a lot)
Language	0	15 (50%)	15 (50%)
Social	0	7 (23%)	23 (77%)
Communication	0	5 (17%)	25 (83%)
Team work	1 (3%)	3 (10%)	26 (87%)
Technical	5 (17%)	12 (40%)	13 (43%)
Management	1 (3%)	13 (43%)	16 (53%)
Creativity	1 (3%)	7 (23%)	22 (73%)
Presentation skills	0	6 (20%)	24 (80%)
Game design	4 (13%)	12 (40%)	14 (47%)
Instructional design	5 (17%)	13 (43%)	12 (40%)
Programming/ coding	8 (27%)	13 (43%)	9 (30%)
Graphics	8 (27%)	14 (47%)	8 (27%)
Animals (context)	3 (10%)	11 (37%)	16 (53%)
Environmental conservation (context)	5 (17%)	12 (40%)	13 (43%)
Evolution theory (context)	10 (33%)	8 (27%)	12 (40%)

Although the heavy workload, all students were explicitly enthusiastic about their participation and the overall outcome of the IP, wondering what could have been realized in more time considering what they had produced in the present small time frame.

We also inquired students about the usefulness of the daily break up meetings and session with mentors. The feedback given by students is shown in Table 3.

Another interesting point to analyze is the internal evaluation made by teams regarding the capabilities demonstrated by each student along the project. The overall results of this evaluation about criteria such as initiative, responsibility, time scheduling, attitude towards working, and cooperation is shown in Table 4. The last column indicates the average final score given by external experts during the presentation of the projects by the teams.

WalkAbout Framework for Contextual Learning Through Mobile Serious Games, Table 3 Perception about the usefulness of feedback sessions

Ranking	How useful were the feedback sessions? [Art/Tech break up]	How useful were the feedback sessions? [Sessions with mentors]
Bad	1 (3%)	0
No use	2 (7%)	0
Good	16 (53%)	7 (23%)
Very good	8 (27%)	13 (43%)
Excellent	3 (10%)	10 (33%)

When we analyze the impact of each criterion in the overall performance of each team, we obtained the following results depicted in Table 5. The results of Table 5 show that cooperation is the main attribute demonstrated by the teams. On the opposite side, deliver work in time scheduling and initiative were the main issues faced by the teams. There is a clear dependence between the initiative and cooperation demonstrated by the teams in terms of the final results obtained by them. On the opposite side, the responsibility does not show to have a deep impact in the overall quality of work developed by the teams.

Exploring the Impact of WalkAbout Initiative

The primary aim of this project was to get students to form international teams and work together on a project. To this end, the project was a big success. From the outset the students engaged in the process. Prior to travel, a Facebook page was set up in the hope that the students would start communicating with each other. The Facebook page, introducing WalkAbout IP, was accompanied by two private groups, one for the participating teachers and one for the participating students. All students were invited to become a member of the student group in order to get to know each other and to start forming teams. The Facebook page was initially used to inform all involved about the proceedings of the preparations of the IP. During and after the IP, participants used the page to publish

WalkAbout Framework for Contextual Learning Through Mobile Serious Games, Table 4 Perception of students capabilities distributed by each group

	Initiative	Responsibility	Time scheduling	Attitude towards working	Cooperation	Final score (external experts)
Animal Quest	4,06	3,88	4,06	3,94	4,31	3,61
Project Bird	3,94	3,81	3,88	3,75	4,25	2,78
Beagle	3,88	4,19	4,19	4,13	4,38	2,50
Mobile Park	3,81	4,00	3,75	4,13	4,00	2,78
A-Team	4,63	4,50	4,63	4,69	4,94	4,72
Make IT Green	4,20	4,20	4,15	4,20	4,50	3,06
Swift	4,44	4,63	4,25	4,31	4,56	3,33

WalkAbout Framework for Contextual Learning Through Mobile Serious Games, Table 5 Impact of students' capabilities in the performance of each team

	Initiative	Responsibility	Time scheduling	Attitude towards working	Cooperation
Mean	4,137	4,173	4,130	4,164	4,420
Biased standard deviation	0,282	0,284	0,262	0,273	0,271
Covariance	0,191	0,108	0,161	0,156	0,171
Correlation	0,843	0,471	0,764	0,706	0,784
Determination	0,710	0,221	0,583	0,499	0,615
T-test	3,498	1,193	2,645	2,232	2,823
p-value	0,017	0,287	0,046	0,076	0,037
Degrees of freedom	5	5	5	5	5

team statuses, social activities, and pictures. Students also expressed their frustrations and achievements on the page. On the first day of the project, the students arrived at the accommodation, from their various countries, at various times. They knew that the following day they were going to be assigned a team in which there would be at most one person from each country. They were informed that they could form their own teams if they wished and the lecturers would create the teams should this not happen. We were pleased to hear that they had all met up with each other during that first evening, mingled well, and had happily assigned themselves to teams before the end of the night. It was felt that allowing them to form their own teams was an important part of them buying into the process. Based on observational data was noted that the students tended to hang around with their team members and not their fellow countrymen. Unfortunately, the home country did not quite have the same

experience. They were not living in the same accommodation as the others, and furthermore, their college was still running (evening) classes as normal. This meant that, in general, there was not the same level of participation from those students. This situation helps to understand the low score of criteria initiative and time scheduling (Table 5).

A secondary aim was to see if we could get the students to produce a prototype mobile game that would have commercial appeal. Again, the project was a success on this front. While each of the seven teams was given the same context, information and set-up they produced very different but thought-provoking concepts mostly aimed at a younger audience. The variety of concepts included using logic puzzles, puzzles involving sound, moral issues, creating personal databases and education. The commercial aspect was evidenced as the National Park requested that two of the games

be worked on further with a view to making them a permanent feature.

A tertiary aim was to test the capabilities of the chosen framework, WalkAbout. Given that the entire project had to take place during 2 weeks, we required a framework that could rapidly turn concepts into games. This framework was designed to use QR codes that, in essence, indexed a database that could be used in both an online and offline setting. WalkAbout is designed to be a platform-independent application so a student only need know about HTML5, CSS, and JavaScript, i.e., no native coding was necessary. The online/offline aspect meant that a person could download a game when they had an internet connection but could then play the game offline. Once an internet connection was reestablished, other features such as leaderboards could be displayed. This was a highly desirable feature as it allowed games to be played in areas where there was no internet coverage or indeed where it was expensive. Thus, a typical game developed by the students involved scanning a QR code and being asked to solve a puzzle, which in turn led the student to another QR code.

While the framework had its limitations, some of these helped the teams focus their attention and home in on a concept quickly. It is worth noting that the students came from a wide variety of backgrounds including tourism, teacher training, applied informatics, games development, and telecommunications, and there was a wide variety in programming skills. That said, each team needed at least one good programmer, as there were many technical issues that needed to be solved during the duration of the project, and unfortunately, the documentation was poor. This was offset by having the framework's creator available during the first week of the project. The need for a good programmer meant that there was a big variety in successfully implementing games. While some managed to produce a fully working prototype, others had to abandon the framework altogether and concentrate on the concept. While WalkAbout performed admirably, we have learned that we need to be careful in our selection of students so that we get a reasonable balance of technically skilled as well

as creative thinkers. Furthermore, it was felt that it would be a good idea to introduce the framework to the technical students in advance. This initiative would help students to increase their learning competences in technical skills, which is one of poorest criterion scored in Table 2.

With regards the methodology, it was felt that we managed to bring out the best in the students. They fully engaged with the project and the words "Intensive Programme" was truly fitting. The feedback sessions were considered very useful by our students (Table 3) and let them to share their thoughts and issues regarding the game design and implementation processes. While the output of the students was undeniably excellent, there were concerns that maybe it was too intensive. There was not much time set aside for relaxation. Also, there were many instances of students staying up all night working, and while they did this out of love of their project, one has to question whether this is a desirable feature of future projects. We should also keep in mind that, for most students, this is taking place near the end of an academic semester, and when they return to their own college, they must reengage in their normal studies.

In looking to the future, we need to review the balance between the desirable aspects, the limitations, and the goals of this project which include:

- The feeling one gets from producing a high quality and commercially viable product.
- The experience of working intensively, within a diverse team, and acquiring the knowledge that this is usually required if a quality product is going to be produced.
- The experience has to take place in under 2 weeks.
- The primary goal is to get students working in international teams.
- The acceptance that some students are nearing the end of their studies and we should not send them home completely exhausted.

While our existing process does a good job of balancing these, it is felt that final point needs to be improved. Although efforts were made to allow thorough communication and information

towards the students' months before the start of the IP, a lot of the information was not received by students. Optimizing communication will allow us to prepare ourselves and the students more and better for the upcoming IP.

Conclusion

The WalkAbout Framework has been explored by teachers, students, and researchers from different nationalities and multidisciplinary domains to create contextual learning environments through the use of mobile serious games. This framework was designed and tested in the context of the Biological Park of Gaia for 2 weeks within a European exchange program. Throughout this period, students from different countries with very different competences, such as IT, education, and social sciences, have created contextual and mobile games involving several technologies, such as mobile networking, mobile programming, object-oriented databases, QR tags, and near-field communication (NFC). These games were previously tested by employees and park visitors.

The creation of immersive learning environments can only be achieved by identifying relevant contextual information. The Biological Park of Gaia was an ideal setting for the students involved in each project to let them realize the importance of perceiving the context in which the game is played, which allowed them to develop new knowledge in botany, biology, and zoology fields.

Interaction among students is a crucial aspect in the development of contextual serious games. The challenge was very demanding as it involved students from various countries. In this sense, teams were built involving students from several countries and with multidisciplinary and complementary competences that guarantee a good balance between technically and creative skilled. Additionally, new friendship relationships were created even after completion of the IP program. This situation was also important in motivating students to carry out an Erasmus+ exchange program throughout their courses.

Offering an immersive experience to the player was another goal of this project. In this sense, each developed game has very different approaches, from adventure games, logic games, action games, multilevel games, among others, which allow players to feel constantly challenged. The possibility to share the players' performance in social networks is also another feature that enhances the disclosure of the games and also raises a greater competitiveness among players.

Finally, it is important that this experience effectively helps students in acquiring new skills. Students from social sciences had the opportunity to collaborate with other students with different competences. This will allow them to better understand the challenges they will encounter in the job market. For their part, students in the IT area have developed new social and technical skills. Although in the context of the course already have knowledge with technologies such as HTML5, JavaScript, and CSS, they did not have yet the opportunity to develop a real project that involved all these technologies. Additionally, they developed new technical competencies in JSON, NFC, and object-oriented databases.

Cross-References

- [Contextual Learning](#)
- [Game-Based Learning](#)
- [Games in Higher Education](#)
- [Games, Simulations, Immersive Environments, and Emerging Technologies](#)
- [Mobile Learning](#)
- [Serious Games](#)
- [Ubiquitous Learning](#)

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Wearable

- [Assisting People with Vision Impairments Through Technology](#)

Web-Based Instruction

- [Distance Learning](#)

Web-Based Learning

- [Assistive Technology and the Gifted Learner](#)

Web-Based Simulation

- [Digital Simulations in Healthcare Education](#)

WhatsApp for Electronic Feedback and Assessment

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Synonyms

[Online communication](#); [Social media](#); [Social networking](#); [WhatsApp](#); [Online messaging platform](#)

Definition

WhatsApp is a free, cross-platform messaging and Voice over IP service owned by Facebook. It allows the sending of text messages and voice calls, as well as video calls, images and other media, documents, and user location.

Alongside social media, mobile instant messaging services such as WhatsApp and Facebook messenger have rapidly transformed the way people communicate. Much like social media, instant messaging platforms are used to connect, collaborate, socialize, and coordinate. They can be used to share images, videos, documents, and audio files, to make calls, and to send texts to individuals or groups of up to 200 people at once. The point of difference from social media is that messages sent via instant messaging services can only be sent to those who are in your contact list; they are not public feeds as per social media.

This entry focuses on how one such instant messaging service – WhatsApp – is used to support learning in higher education. WhatsApp has emerged as one of the most popular instant messaging services for smartphones. It is used by more than one billion people in over 180 countries and is the most popular mobile instant messaging app used in the Middle East region. WhatsApp is used widely across many fields including in the dissemination of political campaign messages, by health professionals to share information about patients, and by the media as a forum to keep updated on the experiences and interests of their readership.

The potential of using WhatsApp to enhance learning is gaining momentum. While research is still in its infancy, the emerging body of literature points to the positive ways this app can be used to provide student feedback and to enhance reflection and learning. Key to these benefits is its easy accessibility, and its low cost (it does not incur any SMS or additional charges to use). This makes it ideal for millennial students who are already high users of online communication tools, plus also for educational use where budgetary constraints can impact on opportunities for educators and students to trial and implement new ways of using technology.

Effective Feedback

A key idea informing the discussion presented in this entry is that feedback is one of the most powerful influences on learning and achievement; this impact however can be either positive or negative. The type of feedback and the way it is given can influence learning differently. Superficial feedback or feedback for feedback's sake has no measurable benefit to learning outcomes. In addition, feedback that is highly critical can cause students to disengage. In their analysis of more than 7000 studies on the implications of feedback on learning and achievement, Hattie and Timperley (2007) conclude that effective feedback is that which is timely (immediate and not delayed); instructional (aims to deepen understanding of the content, is specific, prompts deeper enquiry and self-adjustments); and supportive (relevant and encouraging, helps them to understand themselves as a learner.)

This entry presents some of the most recent research that has been undertaken of the use of WhatsApp in higher education in relation to student feedback, reflection, and learning. Much of this research has been undertaken in developing countries such as Africa and the Middle East where use of WhatsApp is very popular. This entry focuses on why this application is being used in the ways it is and the educational value that is emerging for tertiary learners. The aim is to support practitioners, academics, and graduate students in their understanding of this new direction in educational technology, so as to make informed decisions on its usefulness and applicability to their current practice and research.

Key Reason for Use of WhatsApp

The rise in use of WhatsApp in education has been organic (as opposed to a planned strategy) and stems from its ease of use and its familiarity to educators and students who already make extensive use of this application in their personal life. For example, of the 200 university students participating in Appiah's (2016) study, 46% used WhatsApp 10 or more times per day; 26% used

it 7–9 times a day; and 13%, use it 1–3 times a day. Other studies have found similar results (Jain et al. 2016). Similarly, Appiah et al. (2016) found that of the 180 university educators participating in their study, 46% use WhatsApp more than 10 times daily, 26% use it 7 times daily, 14% others use it maximum of 3 times daily, and 12% used it 4–6 times every day.

Familiarity with an online application eases the physical and mental effort needed to use it, and this positively influences attitudes and openness as an e-learning platform. Building on their familiarity, educators and students have begun using WhatsApp as an alternative to using university email or online learning management systems (LMS) for online communication, collaboration, and access to learning materials. LMSs are routinely made available in higher education for educators to make announcements, to share ideas and resources, and to implement online discussions with students. Research (Wilcox et al. 2016) however shows disconnect between design and usability. LMS are most effectively used on laptops; however students often use smartphones to access a LMS. As a result, the interface, navigation, and features of the LMS for smartphone use is very limited; often it cannot even be viewed on smartphones. Notifications are not received if your question has been answered or if new files have been uploaded, and multiple log-ins may also be required with each follow-up visit to a LMS. This creates a tedious usability issue for the students and instructors (Wilcox et al. 2016) and effects the ability and inclination of students to use this platform to access content, connect with their educator, and connect with peers.

WhatsApp provides the same built-in functions to an LMS yet offers considerable enhanced ease in accessing them. It can be easily retrieved via a smartphone and does not require multiple log-ins with each use. This combination is much more conducive to educators and students continuing their communication beyond the classroom and can supplement or replace technologies beyond those provided by the university to support their social interactions and participation in their learning.

How WhatsApp Is Used and Benefits

Research (Raiman et al. 2017; Doolan and Gilbert 2017) shows that students and educators use WhatsApp as a back-channel for connecting with each other and accessing learning materials outside the classroom, student-to-student, and/or student-educator. A key benefit of value to students and to educators is that the informal shared discussions contribute to fostering an inclusive learning community that builds confidence, reflection, and responsive feedback. On the other hand, educators can experience the expectation that they are available 24/7 to be an imposition on their time and personal life and exacerbating an already demanding teaching role. The following section provides an overview of the key advantages and disadvantages identified in recent literature for using WhatsApp in higher education.

Student to Student

Research shows that students use WhatsApp to help other students by sharing content, experiences, and/or insights with each other. They regularly use WhatsApp for sharing materials such as images and sketches of work undertaken (Appiah 2016; Raiman et al. 2017). Students find value in using WhatsApp for real-time discussions occurring at key learning times such as when putting together their evidence for the final assessment (Jain et al. 2016; Doolan and Gilbert 2017). In comparisons to a LMS, students participating in Doolan and Gilbert's study (Doolan and Gilbert 2017) valued the app as, "a far quicker and more responsive way of communication"; it enables "increased productivity and friendships as everyone could speak with everyone in the group," and it's "simplicity and because we all use it already." The specific and targeted advice occurring in WhatsApp group chats between students importantly facilitate relevant and encouraging advice and feedback that prompts deeper inquiry and self-adjustment (Hattie and Timperley 2007).

Students experienced WhatsApp participation created a more inclusive learning group that contributed to breaking down barriers commonly experienced in the classroom. For example, students in Jain et al. (2016) study considered the

sharing of ideas informally online, strengthened the bond between them, and helped develop their confidence as learners. This study showed that students felt encouraged by their peers to share and articulate further ideas. WhatsApp chats circumvent the time restraints of classrooms that may limit opportunities for students to speak and what some students consider to be an uncomfortable or confrontational environment for "taking the floor" and openly reflecting on the content.

Similarly, other research found WhatsApp participation alleviated difficulties caused by over-talkative students taking over classroom discussion, use of WhatsApp allowed others to be heard (Doolan and Gilbert 2017). Ongoing opportunities to articulate, clarify, and reflect on the curriculum content with their peers and to receive feedback increased their control and independence as learners (Bere and Rambe 2016) and enhanced the academic performance of students (Doolan and Gilbert 2017). Explanation by one student from Naidoo and Kopung's (2016) study is representative of this thinking, "...the WhatsApp instant messaging made me realize the worth of my classmates. Contributions they made significantly contributed to my knowledge of mathematics. I learnt a lot of mathematical concepts and problem-solving strategies from my classmates..."

Educator to Student

The value of the frequent student-educator communication that takes place using WhatsApp is another important benefit emerging in the research. The use of WhatsApp facilitates forming learning communities of students and educators engaging in academic dialogue, with a focus on information sharing, clarification, and further application of knowledge (Jain et al. 2016; Raiman et al. 2017). Of significance is that the communication via WhatsApp is sought out and initiated by students and by educators, suggesting its usefulness for both stakeholder groups. Approximately 50% of students use WhatsApp for teacher availability (Appiah 2016). Similarly, it is used by educators to build a sense of community to develop a deeper acquaintance with students 60%, sense of

belonging to the group 38%, and quality of expression among student 46% (Appiah et al. 2016).

The app is used in student-educator communication to ask and reply to questions and concerns, to contribute to group chats (with all students enrolled in the subjects as well as in subgroups of students), and to upload resources to each other (Appiah 2016). Through group chats, students also have the opportunity to witness faculty interacting with other students and learn from such interactions. Students also valued the opportunity to read and re-read feedback by educators “I can always refer back to the previous messages so that I won’t forgot the old information when I do revisions” (Jain et al. 2016).

The faculty member’s availability and helpfulness and quality and frequency of feedback had a significant impact on student experience (Jain et al. 2016). Targeted talk and focused explanation that addressed the queries of individual needs, corrected or reinforced knowledge, and promoted reflection by both educator and students had a positive effect on students’ sense of connection to the subject and to the educator (Jain et al. 2016). Group chat also facilitates the opportunity for educators to communicate sporadic learning opportunities to students for students to apply their learning, for example, its use by tutors with medical students, “There’s an ABPI that needs doing on [Ward name] if you want to join” (Raiman et al. 2017). Students also reported being more engaged when in class as a result of instant messaging: “Messaging made the session far more stimulating. We were able to focus on specific problems we had in the session. This made the whole learning experience far more useful and specific to us” (Raiman et al. 2017).

The research indicates that the use of WhatsApp by educators and students is conducive to providing quality feedback that is immediate, targeted, relevant and encouraging, and constructive. This is facilitated by the real-time and any-time discussion students could participate in with their peers and educators. Such feedback provided students the opportunity and encouragement to correct mistakes immediately and prompted deeper enquiry and self-adjustment (Hattie and Timperley 2007).

Challenges

While the advantages of using WhatsApp instant messaging have been discussed above, WhatsApp instant messaging can pose educational challenges. Given that a single-text message is restrained to 139 characters, the short message length and succinctness of language required can pose limitations. The limited keyboard can also hinder questions or discussion of particular curriculum content, for example, using content such as mathematical symbols which are not part of the allocated keyboard (Naidoo and Kopung 2016). This can lead to limitations when ask or respond to question or completely avoiding some questions because it would be difficult to write them on WhatsApp instant messaging.

While some research indicates that students and educators view group messages as positive, and comparable to the social messages they receive from their other WhatsApp contacts (Raimen et al. 2017), intrusion on personal time and unwanted extracurricular work can contribute to reluctance to use WhatsApp for educational purposes (Susilo 2014). Message flooding, highly time-consuming, group maintenance, expectation for high availability of teachers, students’ usage of inappropriate language, and overexposure to students’ personal life are challenges to educators’ commitment to using it to promote feedback and reflection (Appiah 2016). Good feedback is that which is well-timed and does not distract from learning (Hattie and Timperley 2007). While this is often considered from the students’ perspective, it is also important to consider “timing” from the perspective of the educator. The use of WhatsApp group chat can exacerbate the time required of educators to fulfill an already demanding role. This may result in less availability or reduced feedback to manage this aspect of feedback.

Conclusion

This entry sheds light on the various benefits of using WhatsApp Group as a platform for

academic discussion to take place. Three features – easy accessibility, minimal cost, and multi-modality features – are important to the effectiveness of its use to provide feedback, support reflection, and promote learning. As the literature indicates, when used well, it creates an organic and iterative learning environment for students. Educators and students become important stakeholders in the process and provide valuable feedback that can be used to refine and improve performance outcomes for everyone (Hattie and Timperley 2007). Several challenges of using WhatsApp include interference with private lives, additional work for educators and improper language use by students. These are important considerations and if not managed well can hinder the benefits of using WhatsApp to promote student learning.

It is hoped that this outline will promote further research among other researchers interested in examining the use of WhatsApp or other instant messaging platforms for teaching and learning purposes. It is also hoped that this entry promotes reflection for practicing teachers and student teachers on the usefulness of WhatsApp for their educational environment. Not all feedback is equal, and not all students and classroom environments are equal. Consideration can be given to the advantages and disadvantages of local use of this app for student learning in the short-term and long-term.

Cross-References

- Challenge of Transforming Curricula with Computers, High Impact Interventions and Disruption
- Collaboration and Social Networking
- Digital Literacy, Creativity, and Autonomous Learning
- Facebook Use in Malaysian Higher Education Classroom
- Social Media for Tertiary Education
- Teacher–Student Relationship and Online Social Networks
- Wikis as a Collaboration Tool

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WhatsApp: Online Messaging Platform

- WhatsApp for Electronic Feedback and Assessment

Why Teach History of Computing?

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Synonyms

Computing history; Computing education; History in computing education

Overview

This entry, an integration of material from earlier works (Impagliazzo 2005; Impagliazzo and Samaka 2013), provides a rationale for incorporating history in computing student experiences. It also shows ways in which computing history can make the delivery of teaching computing courses relevant. The approach suggests the use of computing history as a recurring theme throughout courses through relevant historical stories or material to enhance course delivery and to capture student interest. The use of computing history often makes positive and constructive improvements in student experiences by making topics more interesting and stimulating. It informs students of nontechnical elements within their computing specialties.

Computing history could be an effective pedagogical tool to teach computing courses (Impagliazzo et al. 1999). History contributes to students' lifelong learning experiences, and it also enables students to gain a better sense of the nature of inquiry, the processes of innovation, and the human dimension. Ideally, it would be good if all computing students had a requirement to take a specialized course on the history of computing. Because of curricular limitations, this option is likely unattainable. Hence, embedding history within courses is more feasible and can become an effective pedagogical tool to teach computing courses.

History enables students to explore computing beyond hardware and software, and it expands

students' views on ways in which computing affects society. For example, diversions could include simple stories used to enhance student learning. Teachers can use computing history as a thread throughout student experiences to foster constructive transformations from sterile factual content to dynamic interludes involving people, places, and events. Teachers could also use computing history as a vehicle for extra credit or topic enrichment, particularly for students who enjoy the softer side of the computing field.

Role of Storytelling

Presenting any history as a series of chronological facts is often uninteresting and could be counterproductive. Alternatively, storytelling within the context of student experiences can enrich a subject while connecting students with human elements and can make computing courses more interesting. Moreover, the computing information and knowledge embedded within these stories are often relevant to some aspect of students' own lives. Hence, they often remember the stories and the computing content within them.

Teachers should adopt more innovative and interesting approaches toward student learning to achieve student success. Computer scientist Christos Papadimitriou stated:

This narrative mode (storytelling) of thought is fundamental for at least two reasons: First, narrative richness is an essential precondition for the self (the converse is, of course, trivial: there can be no narration without narrator). We think of ourselves almost exclusively in terms of our mental autobiography. Second, stories are in a certain intrinsic sense interesting, in that they are attractive, high-priority memory fodder. Everything else being equal, we are much more likely to remember a story than a logical argument. (Papadimitriou 2003)

This statement is very true. Students, especially those not specializing in computing, are more likely to remember a story about computing than a fact concerning it.

While storytelling could be quite effective, teachers should not expect that using this technique is always easy. Stories should evolve naturally and they must relate to the topic under discussion.

Sources for such stories could emerge from current happenings or events such as a newspaper article, or they might build on some historical background such as a book on computing history. Whatever the source, teachers should try to research historical topics, so the stories they tell are meaningful to the topic. Storytelling associates students with different perspectives toward computing, and it connects them with people, places, and events. Therefore, active involvement by teachers coupled with active participation by students can make historical storytelling a memorable component to all computing courses.

Relevance and Computing History

Teachers can use history as a vehicle to enrich specialized course studies and to derive other benefits from learning. One reason is the necessity of understanding and critical thinking. Another is the adage of heeding the past to avoid repeating the future. Indeed, the statement by George Santayana that states “Those who cannot remember the past are condemned to repeat it” (Santayana 1905) already exists within the fabric of the computing field. There are many stories on repeating the mistakes of prior happenings; many are well known. For example, how can we explain the cause for the downfall and ultimate demise of Control Data Corporation (CDC)? What caused Digital Equipment Corporation (DEC) to fail? In the mid-2000s, IBM surrendered its personal computer business to Lenovo. Why did IBM do this when “Big Blue” was synonymous with computing machines? Answers to such questions are quite complex. Nevertheless, the questions do form a starting point for student interaction in a classroom setting and for stimulating new ideas and concepts. For some students, they may even provide a basis for more exploratory study and research.

Computing history also provides fodder for curiosity and intrigue. For example, as far back as 2001, Microsoft started developing its Surface computer, which became a reality as a coffee table in 2004 and formally unveiled in 2007 (CNN 2012). Yet, other companies have exploited that technology in the manufacturing

of tablets and smartphones in the latter part of that decade. Exploring reasons why a company develops a technology while competitors take advantage of it could be an effective way to engage students in a topic and promote frank or even heated class discussions.

Curiosity is another trait of history. Why did company X do this? Why didn’t industry Y do that? How did someone come up with an idea such as Z? It is important to dismiss the notion that the only concern of history is on events from the past. Answers to questions as just mentioned can make history futuristic. Building on the past successes of others is useful in a modern age; avoiding the mistakes of others is even more useful.

Computing professionals (practitioners and teachers) have often ignored the history of their field. They often favor innovative approaches while disregarding the past. Although some organizations have contributed to history preservation, the contributions are isolated and often incomplete. Specialized textbooks on technical subjects often do not contain elements on the history of the subject, and when they do, they often contain myths and inaccuracies. However, in recent times, a resurgence is developing where greater awareness of computing history is making strides. Websites such as the IT History Society and conferences such as those held by the Society for the History of Technology (SHOT) address the importance of the topic.

History Within Courses

The following briefly illustrates ways in which computing history can complement and enrich some of the computing courses found in a computing curriculum.

History and Computer Architecture

Computer architecture courses are one area where the history of the subject has received attention. Many textbooks in this area often contain sections, appendices, or sidebar vignettes that contain images that support the machines under discussion. Students often find such historical attention interesting and revealing.

Introducing students to computers without discussing their “invention” leaves a void in their education and a lost opportunity to question the inspiration of pioneers. For example, one might start a course with the question, “Who invented the computer?” and admonish those students who quickly utter “Bill Gates” or “Steve Jobs” in response. A homework activity can surface and names such as Babbage, Turing, Atanasoff, Zuse, and Mauchly emerge. A few students can “get hooked” into the intrigue, and before long, they develop an interest in computing history. The question of the invention of the computer is complex and is not within the scope of this narrative. Nevertheless, it does provide a good starting point to engage students in seeking answers to legal and ethical questions.

It is natural that computers become part of computing history since computing machines are tangible artifacts and have easy recognition by most people, even to nonspecialists in computing. Additionally, teachers wonder sometimes whether students have ever seen the internals of a computer and its electrical and electronic elements such as resistors, capacitors, flash memory chips, busses, or motherboards. More importantly, do these computing specialists know the way these elements work? Notwithstanding, an overview of the history of the subject would naturally expose such elements at least through images if not through visits to computing museums such as the Computer History Museum in California, the Science Museum in London, or the Deutsches Museum in Munich.

History and Computer Networks

Communication networks is another area where computing history received attention. The Internet as we know it has propelled much of this attention. Making this topic relevant in a modern communications course adds meaning and interesting knowledge. We could trace the root of the Internet to 1957 when the former Soviet Union successfully launched Sputnik. Students might ask, what does Sputnik have to do with the Internet? In response to Sputnik’s launch, the United States formed the Advanced Research Projects Agency (ARPA) in 1958 within its

Department of Defense (DoD). The purpose of ARPA was to establish a military advantage in science and technology, since a satellite launch from a seemingly adverse country posed a national security threat.

Students find stories such as this one rather fascinating. They provide fodder for further exploration on topics such as:

- How many nodes were on the original Internet?
- How many nodes are on the Internet today?
- How does one count such nodes and who does the counting?
- How does the Internet contrast with the World Wide Web?
- Are the Internet and the World Wide Web the same thing?
- If not, how do they differ?
- Can one exist without the other?

These and other related questions lead to formal and interpersonal discussions that open new areas of knowledge. This approach adds relevancy and enrichment to a topic or subject and makes network or communications classes more inviting.

History and Introductory Courses

In any curriculum, introductory courses often serve as the key to stimulate and maintain students’ interest and enthusiasm in the subject. They serve in some cases as an enrichment experience for the subject, and they might even serve as a general institutional requirement. Introductory courses also encourage students to develop some understanding of the subject’s concepts and fundamentals and, where appropriate, to develop skills that will serve them in future studies. Within an introductory computing course, the inclusion of historical elements has the advantage of making students think beyond the normal computing topics.

The use of history in a computing overview course is ideal. The broad scope of the overview course, often taken students from different specialties, shows students that the field of computing is more than a narrow orientation.

In fact, it is more about an exploration of computing where teachers can easily tailor history into its syllabus. The overview course presents many opportunities for students to explore extensions of topics on their own. Students tend to appreciate historical excursions, and they can relate their finding to relevant topics in their contemporary settings.

History and Other Specialized Courses

Teachers can use computing history in other computing subject areas as a vehicle to generate some excitement and interest. However, the “show-and-tell” strategy can become limited. With integrated networks and “system on a chip” (SOC) technologies in today’s world, it is difficult to demonstrate physical entities compared to demonstrations of valves or vacuum tubes, transistors, floppy disks, and the like that we could do with computers from the past. Yet, even though an entire computer system is in the shape of a small geometric entity or cube, it is possible to establish interesting stories such as the evolution of the ENIAC that occupied a large room to modern versions of SOC’s.

The strategy of show-and-tell becomes even more limited as we move away from tangible computing entities to intangible ones. What would one show physically about software other than a package or a download of a language product or an operating system? Yet their history remains rich. For example, students could trace the ancestry of a modern language such as C#. The same is true with operating systems. Teachers can pose interesting questions such as what is the status of COBOL and FORTRAN languages or why did the IBM OS2 operating system die.

Many charts and timelines exist on tracing the roots of computing languages and operating systems. We have marveled at the way students enjoy the fascination of seeing ways in which different languages emerged. Additionally, we see that students do appreciate exploring the relevancy of past languages to the languages in use today. With operating systems, student response to learning historical connections is similar. Students can develop a keen interest in the

study of the origins of programming languages and operating systems where teachers can direct them to communities of special interest such as SIGPLAN of ACM or to some specialized literature of books. The proceedings of two conferences, namely, the “History of Programming Languages” (HOPL) in 1978 (Wexelblat 1981) and in 1993 (Bergin and Gibson 1996), are good examples of such works. Here again, an optional assignment on a relevant topic would enrich a class related to software.

The field of computing has a long list of historical contributors such as Leonhard Euler, John von Neumann, and Maurice Wilkes in addition to more contemporary individuals such as Bill Gates, Steve Jobs, Mark Zuckerberg, Larry Page, and Sergey Brin. Whether centuries ago (e.g., Euler), decades ago (e.g., von Neumann), or contemporary pioneers (e.g., Gates), students can become interested in the way their subject evolved over time and how individuals shaped and reshaped the computing field.

Limitations

Embedding history in computing courses often depends on the initiative of the instructor. In general, computing teachers never studied such history in formal settings unless they enrolled in a course through their own initiative. Teachers often need to bootstrap themselves and make some effort to incorporate historical topics in their courses. However, the results derived from such engagement are rewarding, and they often outweigh the cost of the effort involved.

Another limitation in developing modules on computing history is the apparent lack of reliable resources, trained teachers, and institutional support. While the belief for using history to complement computing courses may be strong, institutional support has often been wanting. One reason for this is that history does not usually lead to industrial development or a business presence. Additionally, history is not a topic that normally attracts research grants when compared to other awards given in the IT field.

IFIP and Computing History

In 1960, UNESCO founded the International Federation for Information Processing (IFIP) as a not-for-profit, nongovernmental organization for national computing societies working in the field of information systems. The IFIP organization consists of technical committees (TCs). One such committee (TC 9) addresses the relationship between computers and society. Established in 1976, TC 9 emphasizes the nontechnical aspects of computers on the society, particularly their effect upon people, groups, and institutions. Among other things, TC 9 addresses the use of computers and their effect upon the social consequences, accountability, responsibilities, and the quality of life of humans.

TC 9, as well as other technical committees, operates within a set of working groups (WGs). WG 9.7 on the history of computing is one such working group. IFIP established WG 9.7 in 1992; John A.N. Lee was its founder. The purpose of the working group includes a forum for information exchange in historiography, providing guidance for the implementation of archives, identifying pioneers, promoting “Pioneers Day” at major events, and promoting the history within appropriate curricula. Its activities also provide an impetus to preserve records and artifacts on information processing throughout the world to address the socio-historical context of computing. Its official website (IFIP 2018) reflects the aims and scope of the working group and other related information.

Conclusion

So, why teach computing history? The discussion contained in this entry provides sufficient reason for including computing history within student experiences. The approach suggests that the effect of engaging students in these subjects provides relevance to technical material that includes people, places, and events. Furthermore, history enriches a topic or course. Teachers and students should avail themselves of the many online resources available to them such as virtual

museums, “walk-through” galleries, and oral histories that provide deeper descriptions and understandings of specialized historical events. A resource such as the *IEEE Annals of the History of Computing* (IEEE 2018) contains many formal articles, memoirs, anecdotes, and obituaries; it also provides a foundation for many stories about computing on a global scale.

Using history to teach computing courses is a useful endeavor. The rewards derived from the *teaching* experience offset the preparation and the effort. The rewards derived from the *learning* experience should leave an impression long after students complete a course. Such aspects of engagement add relevance to topics students learn as they prepare themselves for professional careers.

Cross-References

- ▶ [Birth of Information Systems Curricula in Victoria in Colleges of Advanced Education and Universities](#)
- ▶ [Computing Curricular Report CE2016, A Summary](#)
- ▶ [Computing Curricular Report IT2017, A Summary](#)
- ▶ [Digital Storytelling in Teaching and Research](#)
- ▶ [Pedagogical Possibilities for the History of Computing](#)

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the means to collaboratively develop web content (Alexander 2006).

Wikis add powerful collaborative dimensions to the classroom by actively involving learners in their own construction of knowledge (Boulos et al. 2006). They offer information sharing and collaboration features, acting as cognitive reflection and intensification tools and aiding the construction of meaning through the self-design of knowledge repositories (Jonassen et al. 1999).

Wikis are known for their ease of use and deployment, making both information sharing and straightforward collaboration possible (Boulos et al. 2006). Further, these tools require minimal technical skill to use their features, allowing users to focus on knowledge creation, information exchange, and collaborative tasks without the challenge of a difficult technological environment (Kirkpatrick 2006).

Wiki

► Social Networking in Higher Education

Wikis as a Collaboration Tool

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Definition

A wiki is an interactive, modifiable, and collaborative website, the contents of which can be edited via web browser; only those granted access can modify site content.

Introduction

Wikis are social networking tools characterized by a high degree of connectivity, providing users

Wiki Defined

In essence, a wiki involves a simplified process of creating HTML pages combined with a system to record each individual change that occurs over time, so that at any time a page can revert to any of its previous forms. A wiki may also include tools that allow the user community to monitor changes in the state of the wiki and discuss issues that emerge. While everyone may view a wiki page, some wikis restrict access to a group of approved members, allowing only those members to edit page content. Others allow anyone to both edit and view content (Olson 2006).

Howard “Ward” Cunningham was the first to devise the concept of the wiki. His WikiWikiWeb first became available on the Internet in March 1995 and was so named because Cunningham envisioned a quickly evolving web and remembered that wikiwiki is a Hawaiian word meaning quick. The original site’s URL included the abbreviation “wiki,” and the short form began to be commonly used (Parker and Chao 2008). The word “wiki” is included in the Oxford English Dictionary and is defined as “A type of web page designed so that its content can be edited

by anyone who accesses it, using a simplified markup language” (“wiki, n.”).

A wiki is a collaborative website made up of reader-modifiable web pages. The content of a wiki can be edited by approved members or in some cases anyone visiting the site, allowing them to easily create and edit web pages collaboratively (Chao 2007). Wikis are not just a tool for collaborative authoring but can also serve as a source of information and knowledge. Wikis allow visitors to engage in learning with each other by using wikis as a collaborative environment in which to construct their knowledge, as well as to engage in dialog and share information among participants in group projects (Boulos et al. 2006).

A wiki is essentially a vast collaboration space that allows knowledge to be organized and cross-linked (Leuf and Cunningham 2001). At the functional level, Leuf and Cunningham (2001) describe the essence of wikis as follows:

- A wiki permits users to edit any page or to create new pages within the wiki site, using only a web browser with no additional add-ons.
- A wiki encourages associative thought by making the creation of page links almost intuitively easy, resulting in meaningful topic associations between pages.
- A wiki does not provide a carefully crafted site for casual visitors but rather seeks to involve the visitor in an ongoing process of creation and collaboration that constantly alters the website content.

Some additional features of wikis include the following:

- Wikis are intended to allow multiple users to create knowledge repositories through collaborative authoring.
- Wikis encourage knowledge sharing around topics, which are expected to evolve and often expand into something of a permanent knowledge base.
- Wikis are useful when information is intended to be modified and enhanced through a collaborative effort (Mader 2006c).

Wikipedia, the web-based, open-access encyclopedia, is the largest and most well-known wiki project (Lamb 2004). It is a multilingual, free content encyclopedia written collaboratively by volunteer contributors and provides the foremost illustration of a well-executed wiki. Wikipedia was formally launched in January 2001 and in 2019 the English wikipedia alone had over 5.8 million articles in approximately 300 languages (List of Wikipedias 9). It currently ranks as the fifth most-visited website worldwide (Alexa Internet 2017). The accuracy of encyclopedic entries on scientific topics in Wikipedia is quite good, with the number of errors in a typical Wikipedia entry being only slightly higher than a comparable entry in Encyclopaedia Britannica, often considered the gold-standard entry-level reference work (Giles 2005; Nature editors 2005).

How Wikis Work

Because wikis are web based, navigation is generally intuitive. The processes of reading and editing a wiki are both quite simple. Wikis are editable through a browser: simply clicking an “edit” link allows the user to make instant revisions (Lamb 2004). Wiki content can be linked and cross-linked, making locating and utilizing information quick and easy. Wikis enable users to easily edit or update an existing webpage; as the user browses a topic to which they can intellectually contribute, they can begin editing the page by clicking the appropriate link and making changes from within their browser. There is no fixed taxonomy since the organization of a wiki is based on user contributions and their collective personality (Howley 2007).

Wikis have two types of writing modes: thread mode and document mode. Thread mode permits users to carry out discussions by posting signed messages to which others respond, and eventually a group of threaded messages evolves. Document mode allows users to create collaborative documents. User additions to the wiki document are unsigned, and multiple authors edit and update the content of the document. Over the passage of time, the content becomes a representation of the

shared knowledge or beliefs of all contributors (Leuf and Cunningham 2001).

Wikis provide a mechanism that records every change that occurs over time as a document evolves through a series of revisions. Each time there is a change to a wiki page, that revision of the content becomes the current version, and an older version is archived. Versions of the document can be compared, and edits can be “rolled back” if necessary. Hence, it is possible to revert a page, if necessary, to any of its previous states.

The administrator of the wiki has control over access, determining which portions are user-editable. Some wikis restrict editing access, allowing only approved members to edit page content, while others provide unrestricted access, allowing anyone to both edit and view content (Olson 2006).

Some wiki systems have added functionalities such as web-based spreadsheets, calendars, photo galleries, private workspaces, WYSIWYG editing, and even integration with centralized content management systems (Lamb 2004).

Social Networking Features

Wikis are characterized by a variety of unique and powerful information sharing and collaboration features and therefore epitomize the definition of social networking (Parker and Chao 2007). Wikis are expressly designed for collaborative authoring, allowing topics to be edited directly and encouraging knowledge sharing around topics. The extremely rich, flexible collaborations made possible by wikis have positive psychological consequences for their participants and powerful competitive ones for their organizations (Evans and Wolf 2005).

The information sharing encouraged by wikis allows everyone to take equal responsibility for the information published (Brännström and Mårtensson 2006). The system is democratic because all participants have an equal voice. Anyone can contribute content or modify content contributed by someone else (Korfiatis and Naeve 2005), fostering the social ties vital for knowledge sharing (Boyd 2003; Gonzalez-Reinhart 2005).

This social environment technically supports the aspirations of individuals to belong and contribute in a group atmosphere (Boyd 2003; Gonzalez-Reinhart 2005). Such group participation among volunteers can create social connections that help realize personal goals (Boyd 2003; Gonzalez-Reinhart 2005).

Wikis foster social relationships over a domain of social actions stemming from the acceptance, objection, or rejection of a contribution (Korfiatis and Naeve 2005). The implicit negotiation process involved in writing and structuring an article is of particular interest from a social research perspective. The submission and assessment process involves interactions that characterize the dynamics of the negotiation process (Korfiatis and Naeve 2005). For example, if a user makes a contribution that is not accepted and ultimately rolled back, the user can review the change log to determine whether one or multiple individuals were responsible for the change. They can resubmit their contribution, in either its original or modified form, and continue the negotiation process. The communication, collaboration, and negotiation features make it possible to reach a determination of what is collectively considered acceptable and pertinent knowledge (Gonzalez-Reinhart 2005).

Wikis mimic physical communities through socialization and the exchange of information, leading to the creation of conversational knowledge (Gonzalez-Reinhart 2005). Wiki-style collaborative efforts establish systems of trust and reputation within communities of practice (Evans 2006). A community of practice is made up of people engaged in collective learning in a shared domain, where learning becomes a collaborative process of a group (Brodahl and Hansen 2014). Wikis provide a platform for communities of practice that facilitates the exchange of knowledge (Fuchs-Kittowski et al. 2004), allowing members of the community to share their knowledge with the group, work together, discuss issues, etc. (Schaffert et al. 2006a).

Wikis have a variety of features fundamental to a successful community of practice, including easy participation, a virtual presence, democratic

participation, a variety of interactions, valuable content, connections to a broader subject field, personal and community identity and interaction, and evolution over time (Schwartz et al. 2004). Wikis allow members of a community of practice to discuss concepts and contribute feedback, adapt to situations in which knowledge changes quickly, and provide a convenient means to contribute (Campanini et al. 2004).

Alternative Online Collaboration tools

Wikis are often compared to blogs because they are both characterized by content generation and extremely easy publishing capabilities. They appeared about the same time, and both offer an easy publishing tool for disseminating information as well as getting feedback from the public. Wikis were intended to allow multiple users to create knowledge repositories, while blogs were intended for use by individuals in writing personal diaries.

Although they are intended for different purposes, the distinctions between them are subtle because they have converged in functionality. However, there are a number of noteworthy differences between wikis and blogs, among them being the way they organize their information and the number of contributors and what the contributors intend to achieve (Doyle 2006).

- Wikis are designed for collaborative authoring, while blogs are more personal and generally written by a single author.
- Wikis typically organize information into topics, while blogs organize information in reverse chronological order. Information in blogs is more of a historical record and rarely changes. Topics in wikis are expected to evolve and often expand into a long-term knowledge base.
- The reverse chronological order of blogs makes it difficult to find and browse through all postings on a particular topic. Wikis do not as easily show when information was contributed or in what order, but do show

topic associations and make it easy to browse (Woolf 2006).

- Wiki content is created by allowing the public to edit topics directly, while blog contents belong to the owner but provide a mechanism for reader comments.
- Wikis encourage knowledge sharing around topics, while blogs often share spontaneous thoughts.
- Blogs are more effective for disseminating information and for enabling feedback while keeping the original text intact. Wikis are the preferred tool when information is intended to be modified and enhanced as part of a collaborative effort (Mader 2006c).

Another online tool related to wikis is Google Docs, a web-based text editor that supports collaborative editing (Gruhn and Hannebauer 2012). Like wikis, Google Docs allows users to create and to share online documents, spreadsheets, presentations, and forms and allows concurrent online editing and collaboration for knowledge building by multiple users with minimal technical knowledge of HTML (Chu et al. 2009). Although a variety of studies classify Google Docs as a wiki (West and West 2009; Orehovački and Babić 2017), it is more accurately classified as a “collaborative writing application,” a form of social media that enables the joint and simultaneous editing of a web page or an online document by at least two users (Archambault et al. 2014).

New users cannot edit a system of linked Google Docs. Thus, there are no notable wiki instances using Google Docs as a platform. Further, wikis require additional capabilities over a web-based text editor like Google Docs. Neff (2013) states some reasons why Google Docs does not serve as a suitable wiki, including the fact that Google Docs is optimized for the printed page rather than online viewing, is always in edit mode, has no mechanism to dynamically embed content or lists of documents in another document, does not link documents as easily as wikis but instead requires interaction with menus/mouse and copying full URLs to documents, and lacks cross-document consistent styling.

Additional salient differentiations between wikis and Google Docs are pointed out by Guhlin (2009), including the following:

- Most wikis allow either anonymous editing or editing by a limited number of approved users, while with Google Docs each document is created by an individual who can then invite collaborators.
- A wiki site is a hyperlinked collection of individual pages, while in Google Docs each document is separate.
- Wikis are updated as needed, usually when new information about the topic becomes available, information changes, or a mistake is found. Docs are usually created and edited for a specific purpose, but they can be saved indefinitely for reuse at a later time.

Current State of Wikis in Education

Many educators have embraced wikis since they facilitate not only communication but also the collaborative finding, shaping, and sharing of knowledge, all of which are quintessential in an educational context (Reinhold 2006). Because both teachers and students can easily create wiki pages with no prior knowledge or skill in web development or programming, the extra time necessary to develop these skills is eliminated. The ability to interact with evolving text over time allows teachers and learners to see assignments as they are drafted, rather than reviewing only the final draft. A wiki can also be extremely useful tool both in online classes and even in traditional classes for asynchronous communication within groups. Wikis can be used in education to support a variety of learning paradigms, including cooperative/collaborative learning and reflective learning.

In a cooperative/collaborative learning environment, students participate in heterogeneous groups intended to support the learning of their individual members. Wikis provide an excellent tool for facilitating computer-supported collaborative learning, i.e., the development of collaboration by means of technology to augment

education (Augar et al. 2004). Wikis can also help enhance peer interaction and group work and can facilitate sharing and distributing knowledge and expertise among a cooperative group of learners (Lipponen 2002). Online collaborative tools like wikis can help to alleviate some of the problems inherent in collaborative learning (Houghton et al. 2017), because they share many of the elements fundamental to a community of practice, including an online presence, a variety of interactions, communication, participation, and relationships to a broader subject field of interest (Brodahl and Hansen 2014). These tools can enhance peer interaction and group work, facilitate sharing, and facilitate the distribution of knowledge and information among a community of learners (Lipponen 2002).

Wikis also facilitate reflective learning and enrich students' experience beyond the specific details of each project, "overlayering this experience with a more general and overarching, personally-constructed viewpoint on design processes, on how we experience and create the designed world in which each person lives – and a conceptual framework that will enable them to quickly develop their understanding further" (Chen et al. 2005). The collaborative nature of wikis shifts the focus from individual learners to a larger community.

Wikis in Education

A literature search reveals the application of wikis across a variety of areas. Mader's wikis in education site (2006b) cites such educational uses as simple webpage creation, group authoring, data collection, class/instructor reviews, project development with peer review, and tracking group projects. His online text (Mader 2006a) contains discussions by several authors of such topics as integrating wikis in instruction through group wiki projects, constructing science knowledge, collaborative writing projects, using wikis within course management systems, and wiki-based collaboration and academic publishing. Fountain's (2005) survey of wiki use in education suggests several additional uses of wikis,

such as co-creating and co-monitoring projects and collaborative concept elaboration.

Reviewing some of the uses of wikis in education reveals a great deal of ingenuity and creativity. Duffy and Bruns (2006) list multiple educational uses of wikis:

- Students can use a wiki to develop research projects, with the wiki providing ongoing documentation of their work.
- Students can summarize their thoughts from prescribed readings, using a wiki to compile a collaborative annotated bibliography.
- Course resources like syllabi and handouts can be published via wiki, allowing students to edit and comment for all to see.
- Teachers can construct knowledge bases on wikis, sharing reflections and thoughts regarding teaching practices, supplemented by versioning and documentation.
- Wikis can assist in mapping concepts by documenting brainstorming activities.
- Editing a given wiki topic can produce a linked network of resources.
- Wikis can be used as a presentation tool, allowing students to directly comment on and revise the presentation content.
- Wikis are ideal for group authoring, pulling group members together and enabling them to build and edit the document on a single, central wiki page.

Similarly, Parker and Chao (2007) note additional educational uses for wikis:

- Project planning and documentation
- Facilitating online learning groups
- Semantic wiki to serve as a mathematical resource
- Course textbook writing
- Student software project collaboration

Lamb (2004) suggests that faculty design teams can utilize wikis to quickly and collaboratively build reference lists and outlines, brainstorm instructional strategies, and capture suggestions. Bergin (2002) discusses a variety of uses for wikis including student homepages,

anonymous feedback, student-created FAQs, suggestions related to the course, infrastructure hints, and discussions.

Naish (2006) describes educational uses for wikis including an information resource, a collaboration tool, a tool for building e-learning content, and as icebreaker tools. Schaffert et al. (2006a) suggest the use of wikis in project-based learning, collaborative story writing, and interdisciplinary and intercultural learning.

Rather than discussing specific uses, Tonkin (2005) groups educational wikis into four basic forms:

- Single-user wiki: allows individuals to collect and edit their thoughts using a web-based environment.
- Lab book wiki: allows students to keep notes online but provides the added benefit of allowing them to be peer reviewed and changed by fellow students.
- Collaborative writing wiki: can be used by a team for joint writing.
- Knowledge base wiki: provides a knowledge repository for a group.

Many studies focus on specific educational uses of wikis in the classroom. Leifer (2015) studied the use of a wiki in helping teach pathology, finding that the use of wikis helped the students create presentations, demonstrate time difference in pathology, and find past results quickly. Schelly et al. (2015) used wiki technology to help train students on how to use a 3d printer, employing the wiki as a supplemental manual or textbook to help the students keep track of the nuances of using a 3d printer. Martinsen and Miller (2016) used wikis to help group compositional foreign language assignments to increase student participation in all aspects of the project, rather than just those for which they were specifically responsible. Allen et al. (2015) used a wiki in a chemistry class as a replacement for a college textbook, finding that the students who used the wiki received similar grades and decreased out-of-class study time.

Chen et al. (2015) used wikis to help coordinate lesson plans for science teachers, comparing

the use of wikis and Google Docs. Lawrie et al. (2016) used wikis as a science laboratory notebook. Cunningham et al. (2016) used wikis as a documentation tool to help collect data for a clinical trial, noting that teamwork and collaboration were increased through wiki use as compared to traditional documentation.

Project-Based Learning

Wikis are very effective for project planning and documentation (Schaffert et al. 2006a). Particularly useful in collaborative class projects, wikis make it possible for students to meet virtually at their convenience and work on projects together (Byron 2005). Geographically dispersed project teams can use wikis as a discussion tool, to share ideas and to develop the project. With all comments and ideas consolidated on one webpage, a wiki provides a clearer picture of team direction than do individual email messages (Naish 2006).

Schaffert et al. (2006b) suggest applications of wikis with regard to project knowledge management, including brainstorming and exchange of ideas, coordination of activities, coordination and records of meetings, and providing a virtual notepad for shared information items.

Houghton et al. (2017) and Davey et al. (2016) identify a range of common problems associated with project-based learning and then examine various techniques and tools like wikis to determine their efficacy in helping to overcome those problems. Chen et al. (2005) observed that wikis help to alleviate one of the more common pedagogical challenges associated with project-based courses, that of students seeing what they have produced but not what they have learned.

Conclusion

The use of wikis has proliferated and become more commonplace as insightful educators continue to envision innovative uses. Creative use of wikis and the opportunities for collaboration that they offer have proven beneficial across the educational community. Wikis excel at connecting

students through interaction and collaboration, empowering education through openness and flexibility.

Today's students will not only manage future business innovations but in many cases will drive them. Collaborative creativity is becoming an increasingly critical business skill. Because so many organizations have adopted wikis or other collaborative tools for internal and external collaboration as well as information dissemination, interacting with them at the educational level better prepares students for the workforce. Educational institutions can add immense value to their graduates by familiarizing students with the technologies that make collaborative networks possible. Educators must ensure that graduates are aware of the business contributions made possible by wikis and other social software, not just as a phenomenon but also as a skill (Evans 2006). Educators can more effectively prepare students to make innovative uses of collaborative software tools by incorporating wikis into the curriculum.

Cross-References

- Collaboration and Social Networking
- Social Media and Networks as Digital Instruction and Learning Platforms
- Using Social Media to Promote Academic Functioning

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Writing

- Exploratory Study Using Self-Regulated Self-Development (SRSD) and Technology in the Context of the Classroom
- Primary School Classroom Writing Interventions Using Technologies

Writing Programs

- Programming and Coding in Secondary Schools

X

XMDD

- eXtreme Model-Driven Development (XMDD)
Technologies as a Hands-On Approach to Software Development Without Coding
- Modeling of Games and Game Strategies

This encyclopedia includes no entries for Y and Z.